

1976

# Key To Microscopic Fragments of Plant Tissue in Prairie Dog Stomachs and Food Habits of Prairie Dogs in South Dakota

Carol A. Summers

Follow this and additional works at: <http://openprairie.sdstate.edu/etd>

 Part of the [Natural Resources and Conservation Commons](#)

---

## Recommended Citation

Summers, Carol A., "Key To Microscopic Fragments of Plant Tissue in Prairie Dog Stomachs and Food Habits of Prairie Dogs in South Dakota" (1976). *Theses and Dissertations*. 244.  
<http://openprairie.sdstate.edu/etd/244>

This Thesis - Open Access is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact [michael.biondo@sdstate.edu](mailto:michael.biondo@sdstate.edu).

KEY TO MICROSCOPIC FRAGMENTS OF PLANT TISSUE IN  
PRAIRIE DOG STOMACHS AND FOOD HABITS OF  
PRAIRIE DOGS IN SOUTH DAKOTA

by

Carol A. Summers

A thesis submitted  
in partial fulfillment of the requirements for the  
degree Master of Science, Major in  
Wildlife and Fisheries Sciences  
South Dakota State University

1976

KEY TO MICROSCOPIC FRAGMENTS OF PLANT TISSUE IN  
PRAIRIE DOG STOMACHS AND FOOD HABITS OF  
PRAIRIE DOGS IN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

## ACKNOWLEDGMENTS

I would like to express my sincere appreciation to Dr. R. L. Linder, Leader, Cooperative Wildlife Research Unit, for his patience and many suggestions throughout the project.

Thanks are extended to Dr. F. Schitoskey, Jr., Assistant Leader, Cooperative Wildlife Research Unit, for his review of the manuscript and technical advice and to Dr. P. A. Vohs, Department Head, Wildlife and Fisheries Sciences, South Dakota State University, for his review of the manuscript.

Appreciation is given to Mr. C. A. Taylor, Plant Taxonomist, South Dakota State University, for his many hours of assistance in reviewing reference material; to Dr. W. L. Tucker, Agriculture Experiment Station Statistician, South Dakota State University, for his guidance in data analysis; and to the personnel at the Badlands National Monument for their cooperation in the field work.

I am indebted to the members of the Wildlife Department at the University of New Hampshire who allowed me to use their facilities while in absentia from South Dakota State University.

Finally I would like to express gratitude to my husband for his support and assistance throughout the project.

I am grateful to the South Dakota Cooperative Wildlife Research Unit (South Dakota Department of Game, Fish, and Parks, Bureau of Sport Fisheries and Wildlife, South Dakota State University, and Wildlife Management Institute cooperating) for financial support.



KEY TO MICROSCOPIC FRAGMENTS OF PLANT TISSUE IN  
PRAIRIE DOG STOMACHS AND FOOD HABITS OF  
PRAIRIE DOGS IN SOUTH DAKOTA

Abstract

Carol A. Summers

The purpose of this study was to (1) develop a reference collection and construct a key of plants occurring on prairie dog towns in southwest South Dakota; (2) determine plant species eaten by prairie dogs by analyzing stomach and pellet samples; and (3) relate the availability of plant species and preference in the feeding habits of prairie dogs.

Two prairie dog towns of different vegetation were studied. Four burrows in each of two vegetative types for each town were randomly selected. Prairie dogs and pellet samples were collected from these burrows; plant cover was measured in four concentric circles for each burrow. Spring, summer, and winter collections were made in 1973.

Slides of leaf, stem, root, flower, and seed material were made for each species in the study areas. Species of grasses and sedges were identified by the occurrence, position, and shape of epidermal structures: macrohairs, microhairs, prickly hairs, papillae, stomata, long cells, short cells, and silica bodies. Diagnostic characteristics of leaf and stem material of forbs were the occurrence, shape, and position of certain epidermal structures: trichomes, stomata, subsidiary cells, crystals, cell walls, and cuticle. The ability of

the investigator to recognize the reference species was demonstrated by analyzing unknown mixtures.

Five major plant species were found to be important in stomach and pellet samples: buffalograss (Buchloe dactyloides), scarlet globemallow (Sphaeralcea coccinea), threadleaf sedge (Carex filifolia), blue grama (Bouteloua gracilis), and western wheatgrass (Agropyron smithii). Seasonal differences for spring and summer were not significant ( $P>0.05$ ). Insect matter and seed material were not important (less than 5 percent). Winter food habits showed an increase in importance of pricklypear cactus (Opuntia polyacantha) and western wheatgrass and a decline in the other major species. There was no increase in root material in winter.

Prairie dogs were selective in their feeding habits. Three species important in the range but avoided in feeding were threeawn (Aristida fendleriana and A. Longiseta), prairie dogweed (Dyssodia papposa), and horseweed (Conyza ramosissima). Results of this study did not differ greatly from other studies except that buffalograss comprised the greatest percentage of the stomach contents.

## TABLE OF CONTENTS

	Page
Introduction .....	1
Literature Review .....	2
Description of Study Area .....	7
Methods and Materials .....	9
Reference Collection and Plant Key .....	9
Food Habits of Prairie Dogs .....	10
Results and Discussion .....	13
Identification of Plant Fragments .....	13
Key to Leaves of Spring and Summer Dicotyledons and Monocotyledons .....	14
Food Habits of Prairie Dogs .....	73
Summary and Conclusions .....	84
Literature Cited .....	85
Appendix .....	89

# LIST OF FIGURES

Figure		Page
1	<u>Amaranthus albus</u> , <u>A. graecizans</u> , <u>Asclepias pumila</u> , <u>Aster ericoides</u> .....	27
2	<u>Aster ericoides</u> , <u>Astragalus</u> <u>agrestis</u> , <u>Chenopodium leptophyllum</u> .....	29
3	<u>Chrysopsis villosa</u> , <u>Conyza canadensis</u> , <u>Conyza ramosissima</u> , <u>Cryptantha minima</u> .....	31
4	<u>Cryptantha minima</u> , <u>Cymopterus acaulis</u> , <u>Draba reptans</u> , <u>Dyssodia papposa</u> .....	33
5	<u>Dyssodia papposa</u> , <u>Euphorbia fendleri</u> , <u>E. glyptosperma</u> , <u>E. marginata</u> , <u>Gaura coccinea</u> .....	35
6	<u>Gaura coccinea</u> , <u>Helianthus</u> spp., <u>Kuhnia eupatorioides</u> .....	37
7	<u>Kuhnia eupatorioides</u> , <u>Lappula</u> spp., <u>Lepidium densiflorum</u> .....	39
8	<u>Liatris punctata</u> , <u>Linum rigidum</u> , <u>Mirabilis linearis</u> .....	41
9	<u>Mirabilis linearis</u> , <u>Monolepis nuttalliana</u> , <u>Oenothera albicaulis</u> , <u>Opuntia polyacantha</u> .....	43
10	<u>Opuntia polyacantha</u> , <u>Oxytropis</u> spp., <u>Plantago patagonica</u> , <u>P. spinulosa</u> .....	45
11	<u>Polygala alba</u> , <u>P. verticillata</u> , <u>Polygonum aviculare</u> .....	47
12	<u>Polygonum aviculare</u> , <u>Psoralea argophylla</u> , <u>P. cuspidata</u> , <u>P. tenuiflora</u> .....	49
13	<u>Psoralea tenuiflora</u> , <u>Ratibida</u> <u>columnifera</u> , <u>Salsola kali</u> .....	51
14	<u>Salvia reflexa</u> , <u>Solanum rostratum</u> , <u>S. triflorum</u> .....	53

Figure		Page
15	<u>Solanum triflorum, Sphaeralcea coccinea,</u> <u>Taraxacum officinale</u> .....	55
16	<u>Taraxacum officinale, Verbena</u> <u>bracteata, Viola nuttallii</u> .....	57
17	<u>Agropyron smithii, Aristida</u> <u>longiseta, A. fendleriana</u> .....	59
18	<u>Aristida longiseta, Bouteloua</u> <u>gracilis</u> .....	61
19	<u>Bromus japonicus, B. tectorum,</u> <u>Buchloe dactyloides</u> .....	63
20	<u>Buchloe dactyloides, Carex</u> <u>filifolia, Festuca octoflora</u> .....	65
21	<u>Festuca octoflora, Munroa squarrosa</u> .....	67
22	<u>Munroa squarrosa, Schedonnardus</u> <u>paniculatus, Sporobolus cryptandrus</u> .....	69
23	<u>Sporobolus cryptandrus</u> .....	71
24	Comparison of the percentage of dry weight of vegetation in stomachs and percentage of vegetative cover in the range survey in the four vegetative covers for May and August .....	80
25	Comparison of the percentage of dry weight of vegetation in stomachs and percentage of vegetative cover in the range survey in the four vegetative covers for May and August .....	81

# LIST OF TABLES

Table		Page
1	Percentages of dry weight (relative density) for plant species in stomach samples of black-tailed prairie dogs collected from Town 11 and Burns Basin in 1973. Trace (tr) is less than 1 percent .....	74
2	Percentages of dry weight (relative density) for plant species in stomach and pellet samples collected from Town 11 and Burns Basin for 14-22 May and 1-14 August 1973. Trace (tr) is less than 1 percent .....	82

## APPENDIX

Appendix	Page
A List of dicotyledons on study areas (Beetle 1970) and species descriptions to Section I of key .....	90
B List of monocotyledons on study areas (Beetle 1970) and species descriptions to Section II of key .....	104
C Supplement to Section I of key .....	113
D Explanation of terminology used in key .....	120
Dicotyledon structures .....	120
Monocotyledon structures .....	124

## INTRODUCTION

The black-tailed prairie dog (Cynomys ludovicianus ludovicianus) is characteristic of the short grass prairie (Koford 1958) and in 1919 occupied an estimated 100 million acres of land in the United States (Nelson 1919). Early studies concluded that prairie dogs competed for forage and space with cattle (Nelson 1918, Bell 1920, Taylor 1920). As a result a campaign was launched to reduce competition by controlling prairie dogs (Bell 1920). The number of acres occupied by prairie dogs was reduced to an estimated 1.5 million acres by 1960 (U.S. Dept. of Interior 1963).

The degree of competition between cattle and prairie dogs is not known. Merriam (1901) calculated that forage consumption of one cow was equivalent to 256 prairie dogs. Taylor and Loftfield (1924) concluded that the Zuni prairie dog (Cynomys gunnisoni zuniensis Holl.) could destroy as much as 80 percent of the forage. To understand prairie dog-cattle competition, the role of the prairie dog in the ecosystem must be studied. Studies of food habits and energetics are the first steps to determine that role.

The objectives of this study were (1) to develop a reference collection and construct a key of plants occurring on prairie dog towns in southwest South Dakota; (2) to determine plant species eaten by prairie dogs; and (3) to relate the availability of plant species and preference in the feeding habits of prairie dogs.



## LITERATURE REVIEW

Baumgartner and Martin (1939) described a microtechnique which circumvented the problem of macroscopically identifying small plant fragments found in the stomachs and feces of animals. The technique utilizes unique characteristics of many specialized cell types of epidermal tissue (Dusi 1949, Metcalfe and Chalk 1950, Davies 1959, Metcalfe 1960, Storr 1961). Furthermore epidermal tissue of plants is covered by a fatty substance called cutin (Fahn 1970). The cuticle resists digestion and passes through the gastrointestinal tract unchanged except for reduction in particle size by mechanical action. These cuticle fragments bear the outline of specialized cell types of the plant epidermis, and the identity of the plant can be ascertained (Hercus 1960). The microtechnique has been used in recent years in many food habit studies of insects, rodents, lagomorphs, cervids, and bovids.

Sparks and Malechek (1968) estimated dry weight percentages in hand-mixed combinations of forbs, grasses, and grass-forbs. They measured frequency of particles on the slides for each species and converted the frequencies to relative density using a table developed by Fracker and Brischle (1944). They found that their estimates (relative density) were approximately a 1:1 ratio with the actual dry weights in the mixtures. They concluded that composition based on dry weights could be predicted by measuring density of particles on the slides. Their technique was based on two assumptions outlined by Curtis and McIntosh (1950): (1) species must be randomly

distributed and (2) density of particles must be such that the most common species does not occur in more than 86 percent of the locations.

Curtis and McIntosh (1950) found that the relationship between frequency and density as given by Fracker and Brischle (1944) was closely approximated by all species that were random regardless of the quadrat size.

The second requirement of Curtis and McIntosh (1950) was a compromise reached after considering several characteristics of an artificial population. They found that if the quadrat size were too large, frequency values for different species would be numerous in the 80 to 100 percent class. When they considered the relationship between relative frequency and quadrat size, they found an optimum quadrat to be four times the mean area of the most abundant species. A larger quadrat size gave relative frequencies that were equal for all species; even rare species attained frequencies close to 100 percent. When the relationship of frequency and quadrat size at different densities was considered, they found that a desirable quadrat size was equal to the mean area of the species with the greatest number of individuals. At this size the densities of all the species showed a linear relationship to frequency; the most abundant species had a frequency of 63 percent with all other species having lower frequencies. Their compromise was a study quadrat which would give frequencies of less than 86 percent for all random species. The quadrat size was two times the mean area of

the most numerous species. This size would give the maximum information about all important species.

Hercus (1960) elucidated the assumptions underlying the micro-technique for food habit studies: (1) to estimate dry weight proportions of ingested material by measuring particle densities in the sample, any given weight of ingested plant species must produce a certain number of identifiable fragments per sample regardless of the species; and (2) plant species must be digested at the same rate in order for proportions of plants in the stomach or fecal sample to accurately approximate the proportions of ingested material. Storr (1961) stated that weight per unit area of leaf material varied between species and between stages of maturity within a species. He suggested that transformation of area of epidermal fragments to dry weight could be achieved by using a conversion factor (total dry weight of a representative shoot of a species divided by total surface area). Sparks and Malechek (1968) concluded that composition based on dry weights could be predicted by measuring density of particles on the slides without using conversion factors which take into account interspecific differences in specific gravity. Sparks and Malechek's (1968) conclusion supports the first assumption by Hercus (1960). However they stated that specific gravities of other species not used in their study could be different than specific gravities for the species used; consequently the 1:1 relationship would not hold for other species or other stages of maturity. This relationship can be checked for any number of species

using their technique.

Cavender and Hansen (1970) have suggested that by grinding esophageal and fecal samples large particles are reduced in size resulting in particles representing a similar weight value. Thus by grinding, differences in specific gravity among species are reduced.

The second assumption of Hercus (1960) that digestion occurs at the same rate seems less acceptable than the first. Norris (1943) found that there was considerable disagreement between the estimated percentages of forage in the stomachs and the actual percentages of forage in rations fed to 19 sheep. He concluded that the various rates of digestion of plant material caused these differences. Storr (1961) concluded that the chief disadvantage of the micro-technique was its inability to accurately represent proportions of annuals. In annuals only the outer epidermal wall is covered with cutin; while in perennials the cutin is deposited on all walls of the cells. Thus in the latter the cutin surrounds the cell and protects it from digestion (Storr 1961). Bergerud and Russell (1964) and Stewart (1967) made similar conclusions about differential digestion among different plant species. Stewart (1967) stated that if proportional data were desired correction factors would be necessary. These correction factors could be established with feeding trials; the factors would eliminate the differences in digestion for different species of plants.

More recent work indicates that the effect of differential

digestion might not be as critical as these earlier studies suggested. Free et al. (1970) recognized that identification of forbs in the feces posed an important problem. Fragile forbs were not as prominent in the feces as more heavily cutinized plants; but they concluded that perennial plants forming more than 5 percent of the diet could be identified and proportionally quantified using the technique of Sparks and Malechek (1968).

Todd and Hansen (1973) found that contents in rumen and pellet samples of four bighorn sheep did not differ significantly. They concluded that the relative number of fragments of each kind of plant remained similar in passing through the digestive tract. They suggested that digestion reduced the mean weight of fragments rather than eliminating the whole fragment. Hansen et al. (1973) made a similar conclusion in their studies of dietary overlap of sheep, cattle, and bison. They stated that even though the assumption of differential digestion was valid, discernible fragments were still present after passing through the gastrointestinal tract. The mean weight loss per plant fragment was greater than the loss of the number of fragments. Even though these more recent studies recognize the value of establishing regressions for use as correction factors, they suggest that the present method with its refined microscopic technique can provide an adequate index to food habits on a proportional basis.

## DESCRIPTION OF STUDY AREA

Two prairie dog towns were studied in southwest South Dakota. Town 11 is located in the Buffalo Gap National Grasslands (U.S. Forest Service) adjacent to the Badlands National Monument (U.S. Park Service). Town Burns Basin is located in the Badlands National Monument.

Two major vegetative types occurred within the boundaries of both towns. The composition of buffalograss vegetative type in Town 11 was mostly grass (95 percent of the cover). Buffalograss (Buchloe dactyloides) (68 percent) and threeawn (Aristida fendleriana and A. longiseta) (12 percent) were the most abundant grasses in the summer. The two major grasses on blue grama vegetative type on Town 11 were blue grama (Bouteloua gracilis) (41 percent of the cover) and buffalograss (27 percent). Forbs comprised 14 percent of the vegetative cover.

Threeawn (33 percent) and buffalograss (19 percent) were the important grasses in the threeawn vegetative type of Burns Basin. The important forbs were scarlet globemallow (Sphaeralcea coccinea) (8 percent), plantain (Plantago aristida, P. patagonica, and P. spinulosa) (5 percent), prairie dogweed (Dyssodia papposa) (9 percent), and horseweed (Conyza ramosissima) (10 percent). Plant cover for dogweed vegetative type on Burns Basin was primarily comprised of forbs (84 percent). The two major grass species were threeawn (7 percent) and tumble grass (Schedonardus paniculatus) (5 percent). The major forb was prairie dogweed (62 percent). Other important forbs were scarlet globemallow (7 percent) and plantain (6 percent).

Climatological data from Cottonwood Experiment Station, about 24 km from the study areas, show an average annual precipitation of 38.4 cm of which 30.2 cm (79 percent) fall during the growing season (April-September) (Spuhler et al. 1968).

Annual average temperature is 8.4 C; the range is from 37.8 C or above in the summer and -23.9 C or lower in the winter (Spuhler et al. 1968). The average date for the last frost in spring is 19 May and the first frost in fall is 22 September. The average growing season is 126 days (Spuhler et al. 1968).

## METHODS AND MATERIALS

### Reference Collection and Plant Key

Samples of 63 plant species found in the study area were collected to prepare reference slides. C. A. Taylor, a plant taxonomist at South Dakota State University, verified plant identifications. Separate slides of leaf, stem, and root material were prepared for each species; slides were made of flower and seed material when available. Plant parts were taken randomly from different specimens and from different positions on the same plant. The parts were ground in a Waring blender for 2 to 3 minutes and washed over a 0.1 mm (200 mesh) screen. Reference slides were prepared as described by Cavender and Hansen (1970).

Species of grasses and sedges were identified by the occurrence, position (over or between veins), and the shape of such specialized leaf and sheath epidermal structures as macrohairs, microhairs, prickly hairs, papillae, stomata, long cells, short cells, and silica bodies. Diagnostic characteristics for leaf and stem material of forbs were the occurrence, shape, and position of certain epidermal structures: trichomes, stomata, subsidiary cells, crystals, cell walls, and cuticle.

To verify the identification of plant species, mixtures were compounded from actively growing plants collected during May and August. Fifteen grass, 10 forb, and 15 grass-forb mixtures were made by weighing ground stem and leaf material of three to six different species for each mixture. The content of the mixtures were unknown



to the investigator during the time of analysis. The procedures used were similar to those used by Sparks and Malechek (1968).

#### Food Habits of Prairie Dogs

Stomachs were removed from prairie dogs collected at four burrows selected randomly in each of the four vegetative types during two collection periods, 14-22 May and 1-14 August 1973. Forty stomachs were collected in May and 56 in August; five fresh pellets were collected from each burrow during each collection period. Fourteen stomachs were also obtained from 24 June to 4 July 1973 and eight on 20 December 1973 from Town 11.

Stomach and pellet contents were thoroughly mixed in water for 1 minute, washed over a 0.1 mm screen, and oven dried at 60° C. Dried stomach and pellet samples were ground over a 1.0 mm screen in a Wiley Mill. Five slides were prepared from each sample using the same procedure as that used for the reference slides. However it was important to randomly distribute the material on the slide and adjust the density of particles so that the frequency of the most common species was not more than 86 percent (Curtis and McIntosh 1950). Random distribution of the fragments was attained by thoroughly mixing the sample and spreading similar sized fragments (from samples ground over 1.0 mm screen) evenly over the slide. A flattened circle of material with a diameter of 7 mm resulted in an average of three fragments in each microscope field.

A compound, binocular microscope at 125 magnification was used to

analyze the slides. Twenty locations were observed per slide. A location was considered that area of the slide that was outlined by the microscope field using the prescribed magnification. The initial location on the slide was randomly selected, and the remaining 19 locations were systematically observed. Fragments that were recognized as epidermal tissue were recorded for each location. Individual trichomes that were not adjoined to a fragment of epidermal tissue were disregarded. Frequency percentages (number of locations per 100 locations) were recorded for each species in the mixture. The frequency percentages were converted to particle density per field using Fracker and Brischle's (1944) table showing frequency-density relationships. The relative density (ratio of the number of particles per field for a species divided by the total number of particles per field for all species) was calculated for each species and expressed as a percentage. The relative density of a species was used as an estimate for relative dry weight in the mixture.

Food habit data were summarized as mean dry weight percentages (relative density) and occurrence percentages for each species for each vegetative type. Individual plant species were recorded only when leaf or stem material could be identified. Root-stem and seed material, plant parts that were not recorded for a particular species but could be recognized as root-stem or seed material, were also recorded. Mean dry weight percentages for vegetative types did not include root-stem or seed material so that dry weights could be compared with availability (cover percentages) of each species.

Preference indices were calculated for each species comprising over 5 percent of the diet in each vegetative type. The index for a given species was calculated by dividing the mean dry weight by percent coverage (Ueckert and Hansen 1971).

Vegetation was surveyed at each burrow during the two collection periods to estimate food availability. Fifteen randomly selected plots (31 x 31 cm) were analyzed in four concentric circles (3, 6, 9, 12 m) around the burrow.

Plant cover was measured by estimating the percentage of the plot area covered by each species. The aerial parts of the plant were projected onto the surface of the ground. Total plant cover and bare ground were estimated in addition to cover of individual species. The percentage of cover was recorded using a scale from Daubenmire (1959). Midpoints were used for interpretation of the field data.

## RESULTS AND DISCUSSION

### Identification of Plant Fragments

The ratio between estimated dry weight (relative density) and actual dry weight was approximately 1:1 for the three categories of unknown mixtures: grasses ( $Y = 1.18 + 0.95 X$ ,  $r^2 = 0.98$ ), forbs ( $Y = 0.44 + 0.98 X$ ,  $r^2 = 0.97$ ), and grass-forbs ( $Y = 1.00 + 0.96 X$ ,  $r^2 = 0.98$ ). Student's  $t$  test showed no significant difference ( $P > 0.05$ ) among the regression equations (Mendenhall 1968) for all three categories or between the equation  $Y = X$  and the individual equations. These results are very similar to those of Sparks and Malechek (1968). A Chi-square analysis (Freese 1960) was not significant ( $P > 0.05$ ) with a designated error of 6 percent of the actual dry weight (grasses:  $\chi = 79.70$ , 63 df; forbs:  $\chi = 59.27$ , 65 df; grass-forbs:  $\chi = 65.32$ , 59 df). These results demonstrate the ability of the investigator to recognize the reference plants by epidermal tissue fragments.

A key was constructed to identify epidermal fragments of plants in stomachs and pellets of prairie dogs collected on the two study towns. Epidermal tissue was the only tissue type used in the key. Epidermal tissue has many specialized cell types that are taxonomically important (Dusi 1949, Metcalfe and Chalk 1950, Davies 1959, Metcalfe 1960, Storr 1961).

Diagnostic structures selected were those that were least susceptible to intraspecific variation and readily visible on fragments characteristic in stomach and pellet samples. Dimensions

were rarely used except when major differences appeared, and no attempt was made to differentiate adaxial and abaxial surfaces.

Species lists and species descriptions for the dicotyledons, and monocotyledons can be found in Appendices A and B respectively. A description of terms used in the key is presented in Appendix D.

Often a fragment could be categorized without using the entire key. Supplements (Appendix C) to the key were designed to circumvent certain couplets in the key and to place the fragment into a category comprised of several species. Then the key was used to identify the fragment to the species or genus level. This provided a more efficient method of identifying fragments.

#### Key to Leaves of Spring and Summer Dicotyledons and Monocotyledons

- 1a. Epidermal cells horizontally arranged and generally forming two zones, costal and intercostal; paracytic stomata arranged in parallel rows; generally two major cell types: long cells and short cells; trichomes limited to papillae, prickles, macrohairs, and microhairs; silica bodies important; includes grasses and sedges.

Section II

- 2a. Epidermal cells generally not horizontally arranged and never forming costal and intercostal zones; stomata of several types, scattered arrangement; epidermal cells not of two specific types, several shapes ranging from polygonal, rectangular, to irregular; trichomes of numerous types; crystals important; includes forbs. Section I

## Section I

- 1a. Hairs present 2
- 1b. Hairs generally absent; many with papillae Subsection A
- 2a. Unicellular hairs present Subsection B.
- 2b. Unicellular hairs absent; uniseriate and multicellular hairs present Subsection C

## Section I: Subsection A

- 1a. Papillae on epidermal surface 2
- 1b. Papillae not present on epidermal surface 7
- 2a. Cuticular papillae 3
- 2b. No cuticular papillae, other types of papillae present 4
- 3a. Anticlinal walls straight, polygonal cells; paracytic Linum rigidum
- 3b. Anticlinal walls not straight, semi-wavy, irregular cells; anomocytic to anisocytic Liatris punctata

- |     |   |   |   |
|-----|---|---|---|
| 4a. | Oblong papillose, papillae present, often elongated   | 5 |   |
| 4b. | Papillae not oblong, conical  | 6 |   |
| 5a. | Diacytic, stomata grouped with larger epidermal cells between groups  |   | <u>Lepidium densiflorum</u>   |
| 5b. | Anisocytic; semi-wavy anticlinal walls  |   | <u>Viola nuttallii</u>  |
| 6a. | Paracytic; hexagonal cells; papillae may become elongate but not papillose  |   | <u>Salsola kali</u>   |
| 6b. | Anisocytic; irregular cells with wavy anticlinal walls  |   | <u>Cymopterus acaulis</u>   |
| 7a. | Margin of leaf smooth; anomocytic; wavy to straight anticlinal walls  |   | <u>Euphorbia fendleri</u><br><u>Euphorbia glyptosperma</u><br><u>Euphorbia marginata</u><br><u>Taraxacum officinale</u> |
| 7b. | Margin of leaf not smooth; bullate or undulating margin   | 8 |   |
| 8a. | No druses present; anomocytic; small, unicellular, cylindrical trichomes seen occasionally  |   | <u>Polygala alba</u><br><u>Polygala verticillata</u>  |
| 8b. | Druses present  | 9 |   |
| 9a. | Paracytic; bullate surface; polygonal cells; striated cuticle   |   | <u>Polygonum aviculare</u>  |
| 9b. | Anomocytic to anisocytic; undulating surface; irregular cells with wavy to semi-wavy anticlinal walls; moniliform uniseriate hairs infrequent |   | <u>Amaranthus albus</u><br><u>Amaranthus graecizans</u>   |

## Section I: Subsection B

- |     |  |   |  |
|-----|--|---|--|
| 1a. | Branched, unicellular hairs  | 2 |  |
| 1b. | Unbranched, unicellular hairs  | 3 |  |
| 2a. | Hair branching into two arms, papillose; raised, circular base   |   | <u>Oxytropis</u> spp.<br><u>Psoralea argophylla</u>  |
| 2b. | Hair branching into two or more prongs, often accompanied by dentiform hairs; circular to whorled base   |   | <u>Draba reptans</u>                                 |
| 3a. | Strand, unicellular hairs  |   | <u>Artemisia frigida</u>                             |
| 3b. | No strand, unicellular hairs present   | 4 |  |
| 4a. | Bristles present   | 5 |  |
| 4b. | No bristles present  | 7 |  |
| 5a. | Uniseriate hairs (in addition to bristles) with oblong to rounded cells tapering to blunt or rounded tip; circular bases of uniseriate hairs; bristles large with pointed ends |   | <u>Salvia reflexa</u>                                |
| 5b. | Uniseriate hairs (in addition to bristles) with rectangular to square cells tapering to pointed tip  | 6 |  |
| 6a. | Bristles large with pointed tip; base of uniseriate hairs whorled or raised, circular  |   | <u>Helianthus</u> spp.                               |
| 6b. | Bristles small with pointed or blunt tip; base of uniseriate hairs circular  |   | <u>Hedeoma hispida</u><br><u>Hedeoma pulegioides</u> |
| 7a. | Cylindrical hairs  | 8 |  |



- |  |    |   |
|--|----|---|
| 7b. No cylindrical hairs;<br>dentiform hairs present   | 9  |   |
| 8a. Stout cylindrical hairs,<br>papillose; some tending to<br>be dentiform; generally<br>geniculate                              |    | <u>Astragalus agrestis</u>  |
| 8b. Slender cylindrical hairs;<br>large dentiform hairs  |    | <u>Oenothera albicaulis</u>   |
| 9a. Medium to short, narrow,<br>papillose, dentiform hairs;<br>if larger hairs present may<br>not be papillose; circular<br>base |    | <u>Gaura coccinea</u>   |
| 9b. No papillose, dentiform<br>hairs; if present very large<br>with thick walls  | 10 |   |
| 10a. Dentiform hairs with<br>raised, circular base   |    | <u>Psoralea cuspidata</u><br><u>Psoralea tenuiflora</u>                     |
| 10b. Dentiform hairs without<br>raised, circular base<br>rather base whorled   | 11 |   |
| 11a. Raphides; oval shaped epidermal<br>cells with straight to semi-<br>wavy anticlinal walls; small,<br>cylindrical hairs       |    | <u>Oenothera albicaulis</u>   |
| 11b. No raphides; irregular cells<br>with wavy anticlinal walls<br>on at least one surface                                       |    | <u>Cryptantha minima</u><br><u>Lappula</u> spp.<br><u>Verbena bracteata</u> |

Section I: Subsection C

- |   |   |
|---|---|
| 1a. No uniseriate hairs,<br>multicellular hairs | 2 |
| 1b. Uniseriate hairs,<br>multicellular hairs    | 5 |

2a. Large, multicellular, glandular hairs; cuticular papillae	<u>Linum rigidum</u>
2b. No large, multicellular, glandular hairs; vesicular, stellate, tufted, or candelabra hairs	3
3a. Vesicular hairs with uniseriate stalks	<u>Chenopodium incanum</u> <u>Chenopodium leptophyllum</u> <u>Monolepis nuttalliana</u>
3b. No vesicular hairs; stellate, candelabra, or tufted hairs	4
4a. Stellate hairs; rosette base	<u>Sphaeralcea coccinea</u>
4b. No stellate hairs; tufted to candelabra hairs; rosette base; small, multicellular glandular hairs	<u>Solanum rostratum</u>
5a. Uniseriate hairs with oblong to round cells tapering to blunt or rounded tip	6
5b. Uniseriate hairs with rectangular to square cells tapering to pointed tip	12
6a. Terminal cell bulbous; modified anisocytic; polygonal epidermal cells	<u>Mirabilis linearis</u>
6b. Terminal cell not bulbous	7
7a. Uniseriate hair not smooth, rather papillose	8
7b. Uniseriate hair smooth	9
8a. Paracytic; terminal cell of hair often club-shaped	<u>Asclepias pumila</u>

8b. Anomocytic; terminal cell of hair tapered; multicellular, glandular hairs	<u>Solanum triflorum</u>
9a. Hairs extremely long with "mesh pattern" on walls; oblong cells often impregnated	<u>Opuntia polyacantha</u>
9b. Hairs short to medium in length	10
10a. Proximal cells round to short ovals; polygonal shaped epidermal cells	<u>Kuhnia eupatorioides</u>
10b. Proximal cells rectangular to oblong	11
11a. Anisocytic; irregular epidermal cells with wavy anticlinal walls; bristles present	<u>Salvia reflexa</u>
11b. Semi-anisocytic; oblong to oval epidermal cells with semi-wavy anticlinal walls, prominent pitting; surface glands	<u>Dyssodia papposa</u>
12a. Hairs composed of thin, elongated cells; raised, circular base	<u>Plantago aristida</u> <u>Plantago patagonica</u> <u>Plantago spinulosa</u>
12b. Hairs not composed of thin, elongated cells	13
13a. Anomocytic; uniseriate hairs generally papillose	14
13b. Anisocytic; uniseriate hairs generally not papillose	15
14a. Uniseriate hairs either with large, raised, circular base or whorled base; large bristles	<u>Helianthus</u> spp. <u>Ratibida columnifera</u>

- 14b. Uniseriate hairs generally with circular bases, not raised or whorled; small bristles with pointed or blunt end  
Hedeoma hispida  
Hedeoma pulegioides
- 15a. Proximal portion of hair (foot) composed of several cells, often impregnated; whorled base; papillose hairs sometimes present  
Conyza canadensis  
Conyza ramosissima
- 15b. Proximal portion of hair (foot) composed of single cell  
16
- 16a. Semi-wavy anticlinal walls of epidermal cells; whorled base; uniseriate hairs with modified terminal cell which is elongated, narrow, and pointed  
Aster ericoides
- 16b. Cells separating subsidiary cells without wavy anticlinal walls; prominent pitting; accessory cells present but not whorled; uniseriate hairs with modified terminal cell which is elongated, narrow, and pointed  
Chrysopsis villosa

## Section II

- 1a. Short cells present  
2
- 1b. No short cells  
Carex filifolia
- 2a. Large area of fragment with exceedingly sinuous long cells interspersed with short cells (usually in pairs); intercostal and costal regions may or may not be distinct; sheath material  
14

- |   |    |  |
|---|----|--|
| 2b. Long cells with normal sinuous or straight walls; fragment divided into zones of costal and intercostal regions; leaf material  | 3  |  |
| 3a. Epidermis with festucoid characteristics; subsidiary cells dome-shaped or parallel-sided; silica bodies (costal) tall and narrow, round, or oblong; microhairs absent | 12 |  |
| 3b. Epidermis with panicoid characteristics; subsidiary cells triangular or dome-shaped; silica bodies (costal) saddle-shaped, cross-shaped, angled, or dumb-bell-shaped  | 4  |  |
| 4a. Costal short cells with dumb-bell-shaped silica bodies  |    | <u>Aristida fendleriana</u><br><u>Aristida longiseta</u> |
| 4b. Costal short cells with silica bodies not dumb-bell-shaped, rather saddle-shaped, cross-shaped, or angled silica bodies   | 5  |  |
| 5a. Costal short cells with square to angled silica bodies, costal short cells saddle-shaped to angled  |    | <u>Schedonnardus paniculatus</u>                         |
| 5b. Costal short cells with saddle-shaped or cross-shaped silica bodies   | 6  |  |
| 6a. Costal short cells with saddle-shaped silica bodies   | 9  |  |
| 6b. Costal short cells with cross-shaped silica bodies  | 7  |  |
| 7a. Cross-shaped costal short cells with similar shaped silica bodies, mostly in singles  | 8  |  |

- 7b. Costal short cells mostly in pairs, with one of the short cells cross-shaped and containing similar shaped silica bodies; microhairs half as wide as long, distal and proximal cells similar in length Munroa squarrosa
- 8a. Microhairs half as wide as long, short with proximal and distal cells of similar lengths Munroa squarrosa
- 8b. Microhairs with proximal cell about twice the length of distal cell, distal cell tapering to extended tip Sporobolus cryptandrus
- 9a. Saddle-shaped costal short cells with similarly shaped silica bodies, generally in singles 11
- 9b. Saddle-shaped costal short cells with similar shaped silica bodies, generally in pairs 10
- 10a. Microhairs half as wide as long, short with proximal and distal cells of similar lengths Munroa squarrosa
- 10b. Microhairs with proximal cell about twice the length of distal cell, distal cell tapering to extended tip Sporobolus cryptandrus
- 11a. Intercostal short cells paired, generally both tall and narrow with one containing similar shaped silica body; microhairs with proximal cell tapering and distal cell elongated and hemispherical Bouteloua gracilis

- 11b. Intercostal short cells in singles with cell tall and narrow with no silica body, in pairs with both cells tall and narrow to square with no silica bodies, and in pairs with one cell smaller, square containing silica body C-to J-shaped, other cell tall and narrow; microhairs with basal cell tapering and more than 4 times the length of the distal cell, distal cell hemispherical and not elongated Buchloe dactyloides
- 12a. Costal short cells in singles or pairs, horizontally elongated cells with rounded ends, silica bodies close fitting with similar shape as cells 13
- 12b. Costal short cells either single, circular, pitted cells or paired circular, pitted cells and tall and narrow cells containing thin, curved silica body Agropyron smithii
- 13a. Intercostal short cells in pairs with one smaller circular cell fitting into tall and narrow cell, silica body thin and curved inside circular cell Festuca octoflora
- 13b. Intercostal short cells in singles with circular, pitted cells and in pairs with one smaller, circular cell fitting into tall and narrow cell, silica body thin and curved inside circular cell Bromus japonicus  
Bromus tectorum
- 14a. Short cells in pairs or singles with silica bodies oval, saddle-shaped, rectangular, cross-shaped, or angled. 16

- |  |    |  |
|--|----|--|
| 14b. Short cells in pairs with one cell very small and circular fitting into tall and narrow cell, circular cell containing thin, curved silica body | 15 |  |
| 15a. Long cells narrow with fine, sinuous walls  |    | <u>Festuca octoflora</u>                                 |
| 15b. Long cells wider with thick, very sinuous walls   |    | <u>Agropyron smithii</u>                                 |
| 16a. Short cells generally in singles; cells saddle-shaped with square to angled silica bodies, a few cross-shaped cells with angled silica bodies   |    | <u>Schedonnardus paniculatus</u>                         |
| 16b. Short cells generally in pairs  | 17 |  |
| 17a. Short cells in pairs with one cell oval, rectangular, or saddle-shaped  | 18 |  |
| 17b. Short cells in pairs with one cell cross-shaped or distortions of cross-shaped  |    | <u>Munroa squarrosa</u>                                  |
| 18a. Short cells in pairs with one cell saddle-shaped or rectangular   | 19 |  |
| 18b. Short cells in pairs with one cell oval containing close fitting oval silica body; macrohairs present   |    | <u>Aristida fendleriana</u><br><u>Aristida longiseta</u> |
| 19a. Short cells in pairs with one cell saddle-shaped other crescent-shaped to rectangular   | 20 |  |



- 19b. Short cells in pairs, both cells tall and narrow with one containing similar shaped silica body; macrohairs present

Bouteloua gracilis

- 20a. Microhairs abundant with basal cell twice the length of the distal cell, distal cell tapering to extended tip

Sporobolus cryptandrus

- 20b. Microhairs less abundant with basal cell tapering and more than 4 times the length of the distal cell, distal cell hemispherical and not elongated

Buchloe dactyloides

Figure 1.

1. Amaranthus albus. 125X Leaf epidermis: anomocytic stomata; irregular cells with wavy anticlinal walls.
2. Amaranthus albus. 125X Leaf: leaf margin undulating; druses.
3. Amaranthus graecizans. 125X Leaf epidermis: anisocytic stomata; irregular cells with semi-wavy anticlinal walls.
4. Amaranthus graecizans. 125X Stem epidermis: uniseriate hair; oblong cluster crystals.
5. Asclepias pumila. 125X Leaf epidermis: paracytic stomata; polygonal cells with straight anticlinal walls.
6. Asclepias pumila. 125X Leaf epidermis: papillose, uniseriate hair with terminal cell enlarged or club-shaped.
7. Asclepias pumila. 125X Stem: papillose, uniseriate hairs with terminal cell enlarged or club-shaped.
8. Asclepias pumila. 125X Stem epidermis: distorted rectangular cells oriented horizontally; druses.
9. Aster ericoides. 125X Leaf epidermis: anisocytic stomata; irregular cells with semi-wavy anticlinal walls.
10. Aster ericoides. 125X Leaf epidermis: whorled bases of uniseriate hairs.

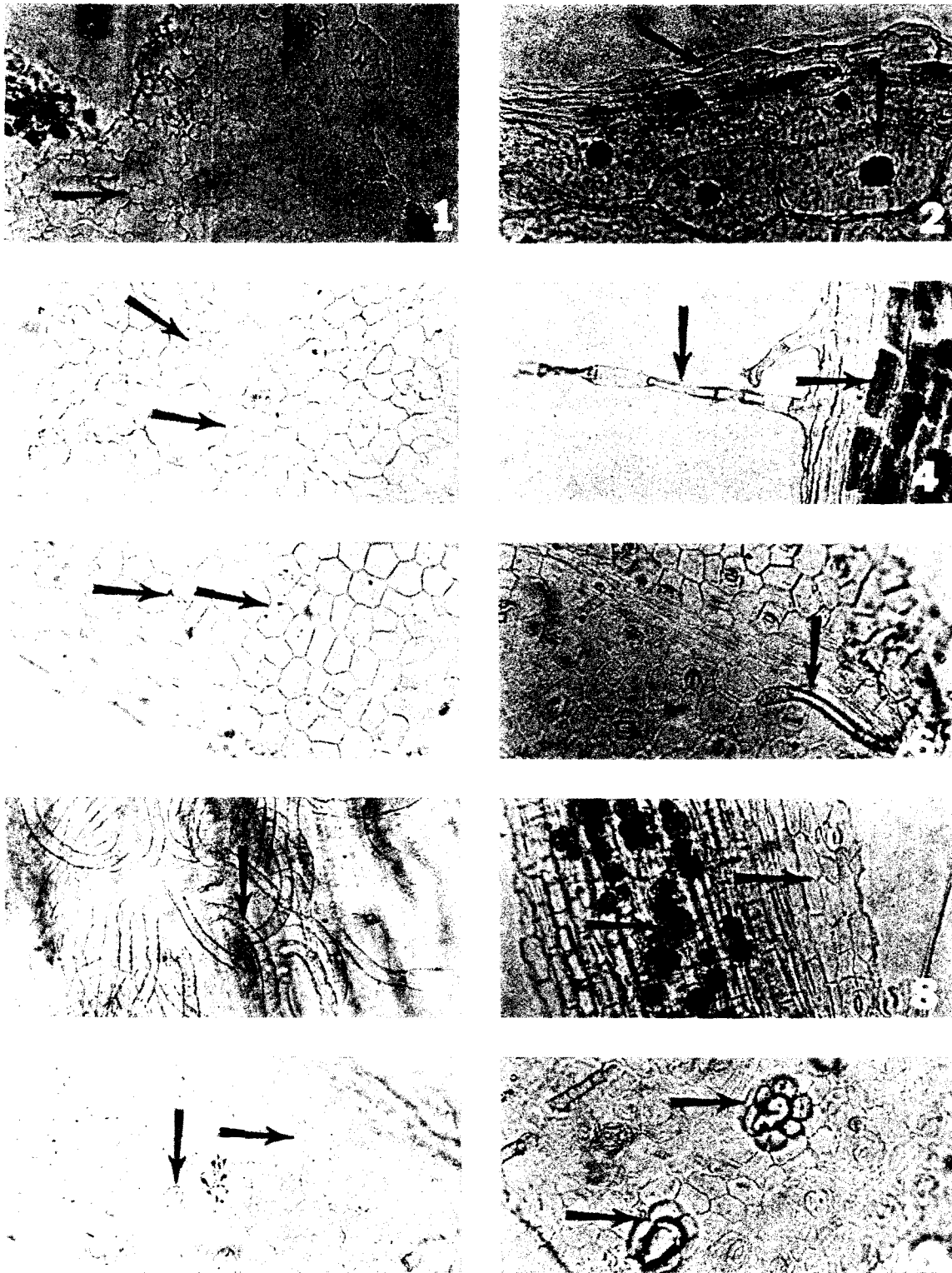


Figure 1.

Figure 2.

1. Aster ericoides. 125X Leaf epidermis: uniseriate hairs with modified terminal cell, elongated, narrowed, and sharply pointed.
2. Aster ericoides. 125X Leaf: uniseriate hairs with rectangular cells tapering to a pointed tip.
3. Aster ericoides. 125X Stem epidermis: anisocytic stomata with subsidiary cells of different shape than other epidermal cells; cells not oriented horizontally.
4. Astragalus agrestis. 125X Leaf: dentiform, papillose, unicellular hairs; raised, circular base.
5. Astragalus agrestis. 125X Leaf epidermis: anomocytic stomata; polygonal to oval cells with straight to semi-wavy anticlinal walls.
6. Astragalus agrestis. 125X Leaf epidermis: cylindrical, papillose, unicellular hairs.
7. Astragalus agrestis. 125X Stem: dentiform, papillose, unicellular hairs; raised, circular base.
8. Chenopodium leptophyllum. 125X Leaf: small circular trichome bases; druses; irregular to oval cells with semi-wavy to straight anticlinal walls.
9. Chenopodium leptophyllum. 125X Leaf epidermis: vesicular hairs; small, circular base.
10. Chenopodium leptophyllum. 125X Leaf: vesicular hairs with uniseriate stalks.

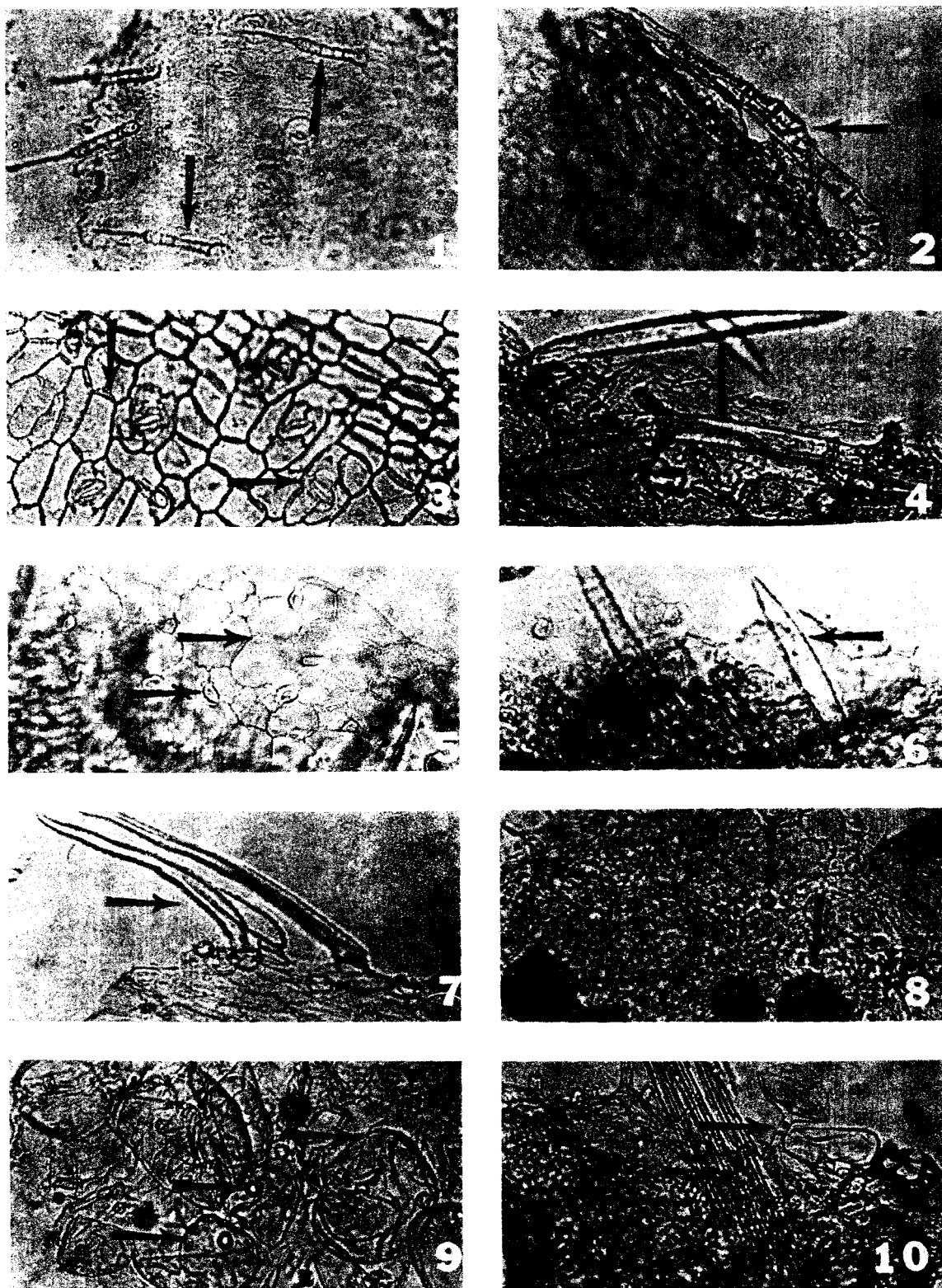


Figure 2.

Figure 3.

1. Chrysopsis villosa. 125X Leaf: uniseriate hairs with rectangular cells tapering to a pointed tip.
2. Chrysopsis villosa. 125X Leaf epidermis: uniseriate hairs with modified terminal cells, elongated, narrowed, and sharply pointed.
3. Chrysopsis villosa. 125X Leaf epidermis: whorled base of uniseriate hair; anisocytic stomata; semi-wavy anticlinal walls with epidermal cells often elongated.
4. Chrysopsis villosa. 125X Leaf epidermis: prominent pitting in epidermal cell walls.
5. Conyza canadensis. 125X Leaf: uniseriate hairs with rectangular cells tapering to a pointed tip; series of oval structures in mesophyll.
6. Conyza canadensis. 125X Leaf: foot of hair composed of several cells.
7. Conyza ramosissima. 125X Leaf epidermis: whorled base of uniseriate hair; anisocytic stomata; irregular shaped cells with semi-wavy to straight anticlinal walls.
8. Conyza ramosissima. 125X Leaf epidermis: uniseriate hairs.
9. Conyza ramosissima. 125X Stem epidermis: uniseriate hairs with rectangular cells tapering to a pointed tip; rectangular cells oriented horizontally.
10. Cryptantha minima. 125X Leaf epidermis: dentiform, unicellular hairs; irregular cells with wavy anticlinal walls.

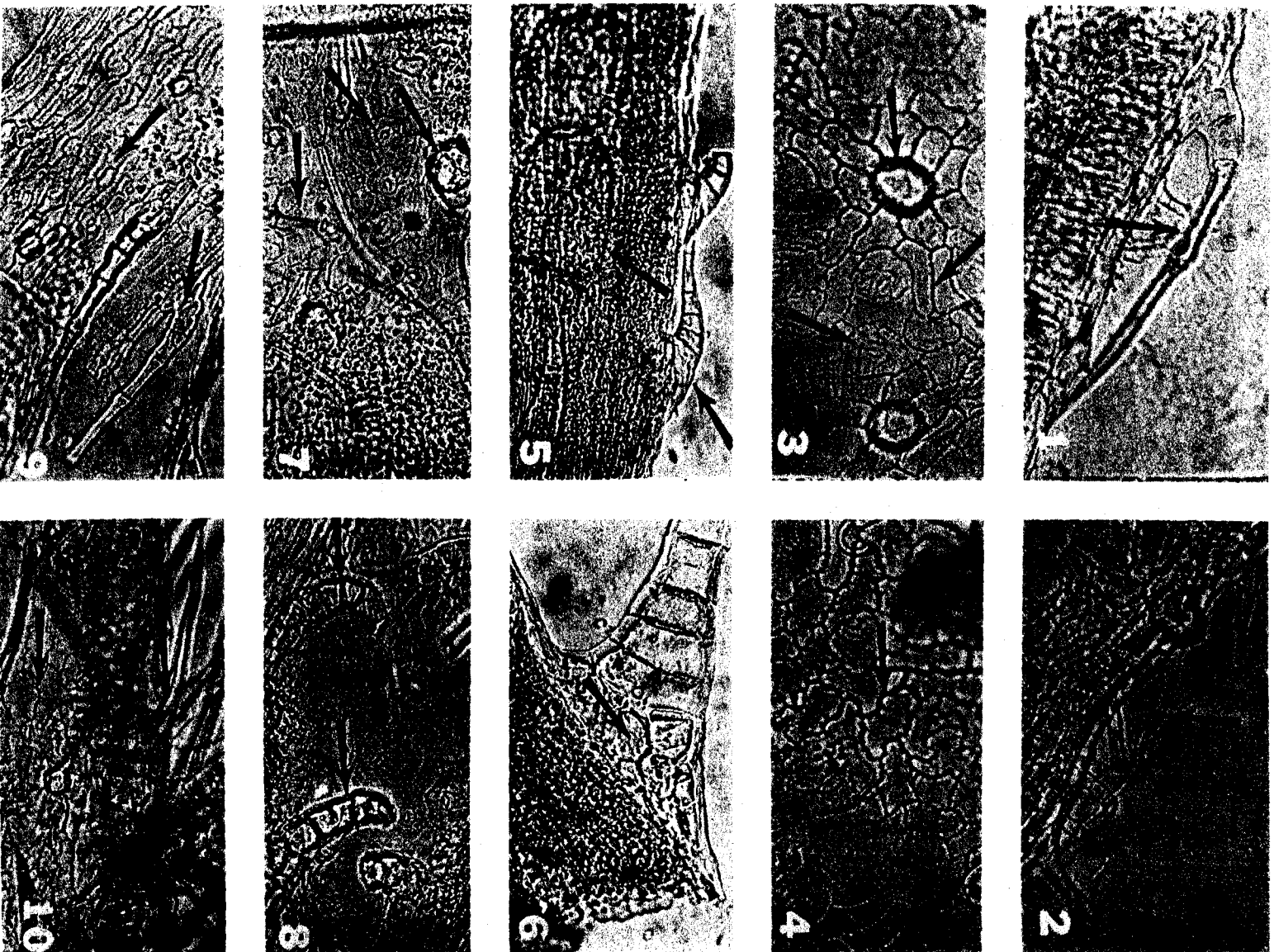


Figure 3.

Figure 4.

1. Cryptantha minima. 125X Leaf epidermis: dentiform, unicellular hair.
2. Cryptantha minima. 125X Leaf epidermis: whorled base; impregnated foot of unicellular hair.
3. Cryptantha minima. 125X Leaf epidermis: anomocytic stomata; irregular cells with wavy anticlinal walls.
4. Cymopterus acaulis. 125X Leaf epidermis: surface muricate with conical papillae.
5. Cymopterus acaulis. 125X Leaf epidermis: anisocytic stomata; irregular cells with wavy anticlinal walls; ridged cuticle.
6. Draba reptans. 125X Leaf: forked, papillose, unicellular hair.
7. Draba reptans. 125X Leaf epidermis: whorled base of unicellular hair.
8. Draba reptans. 125X Leaf epidermis: anomocytic stomata; irregular cells with wavy anticlinal walls.
9. Draba reptans. 125X Stem epidermis: forked, unicellular hair; irregular cells oriented horizontally.
10. Dyssodia papposa. 125X Stem epidermis: uniseriate hairs with oblong cells tapering to a rounded tip; irregular cells oriented horizontally.



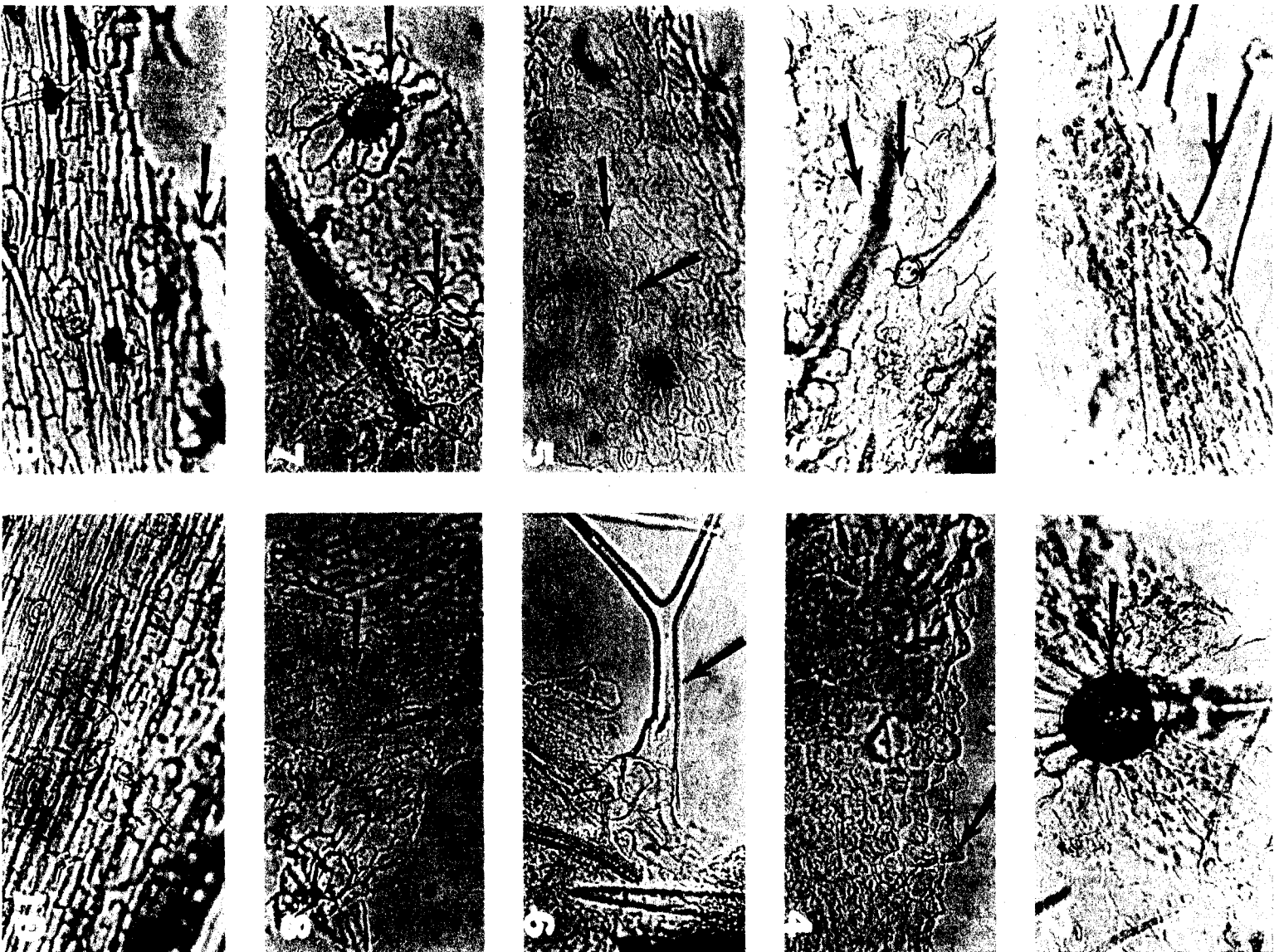


Figure 4.

Figure 5.

1. Dyssodia papposa. 125X Leaf: uniseriate hairs with oblong cells tapering to a rounded tip.
2. Dyssodia papposa. 125X Leaf epidermis: semi-anisocytic stomata; oblong to oval cells with semi-wavy to straight anticlinal walls with prominent pitting.
3. Dyssodia papposa. 125X Leaf: surface gland.
4. Euphorbia fendleri. 125X Leaf epidermis: glabrous, smooth margin; polygonal cells with straight anticlinal walls.
5. Euphorbia fendleri. 125X Leaf epidermis: anomocytic stomata; irregular cells with wavy anticlinal walls.
6. Euphorbia glyptosperma. 125X Leaf epidermis: glabrous, undulating margin.
7. Euphorbia glyptosperma. 125X Leaf epidermis: anomocytic stomata; irregular cells with wavy anticlinal walls.
8. Euphorbia marginata. 125X Leaf: strand, unicellular hair.
9. Euphorbia marginata. 125X Leaf epidermis: anomocytic stomata; polygonal cells with straight anticlinal walls.
10. Gaura coccinea. 125X Stem epidermis: medium to short papillose, dentiform unicellular hairs; occasionally larger dentiform hair.

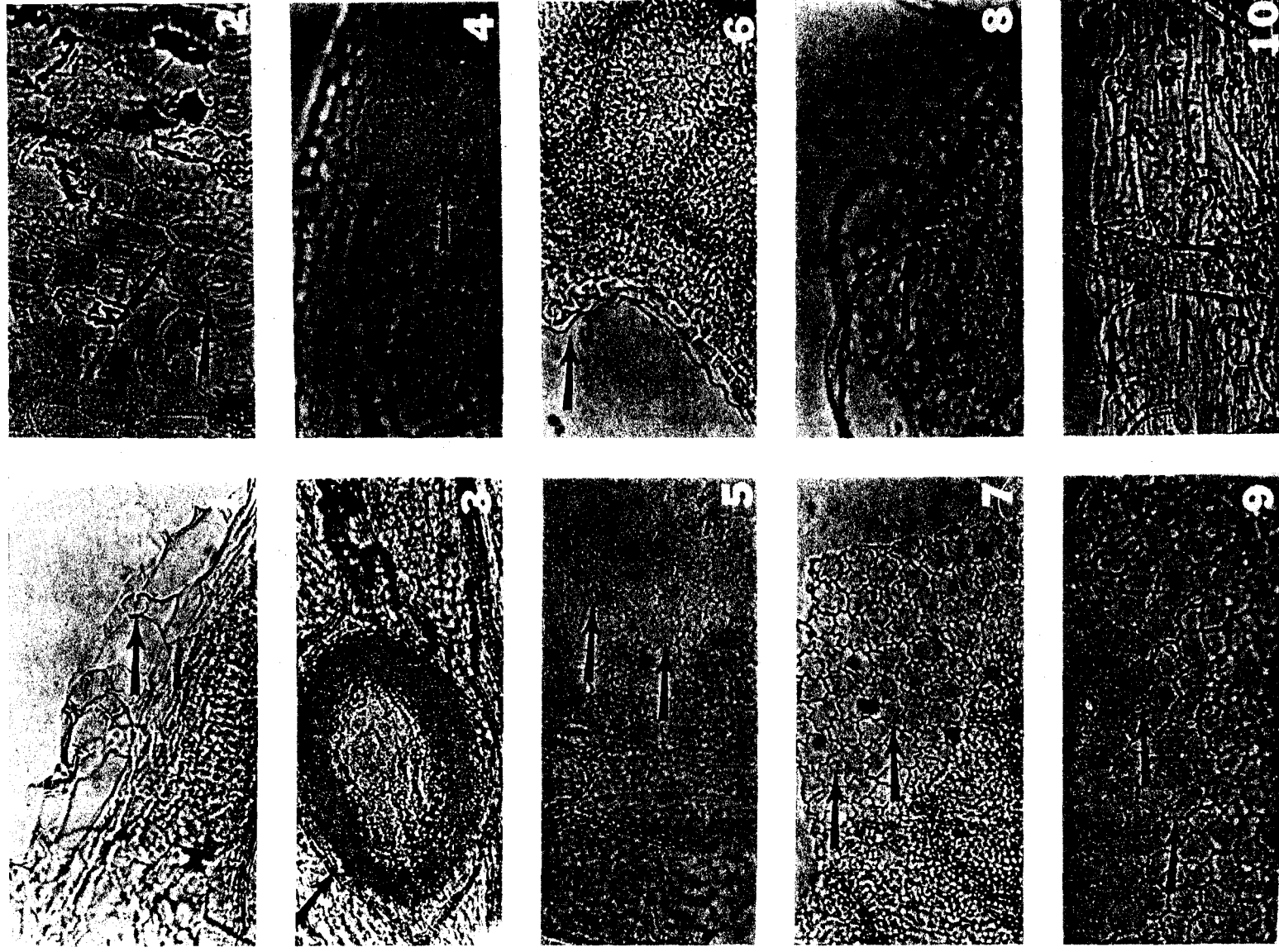


Figure 5.

Figure 6.

1. Gaura coccinea. 125X Leaf: papillose, dentiform unicellular hairs.
2. Gaura coccinea. 125X Leaf epidermis: circular base of unicellular hair; anomocytic stomata; irregular cells with wavy anticlinal walls.
3. Gaura coccinea. 125X Leaf epidermis: anomocytic stomata; irregular cells with wavy to semi-wavy anticlinal walls.
4. Helianthus spp. 125X Leaf: uniseriate hair with rectangular cells tapering to a pointed tip.
5. Helianthus spp. 125X Leaf epidermis: uniseriate hairs.
6. Helianthus spp. 125X Leaf epidermis: raised, circular base of uniseriate hair; anomocytic stomata; irregular cells with wavy anticlinal walls.
7. Helianthus spp. 125X Leaf epidermis: anomocytic stomata; irregular cells with wavy anticlinal walls.
8. Kuhnia eupatorioides. 125X Leaf: uniseriate hairs with rounded cells tapering to oblong terminal cell, proximal portion of hair moniliform; uniseriate hairs with terminal cell bulbous.
9. Kuhnia eupatorioides. 125X Leaf epidermis: uniseriate hairs with rounded cells tapering to oblong terminal cell; uniseriate hairs with terminal cell bulbous.
10. Kuhnia eupatorioides. 125X Leaf epidermis: anomocytic stomata; polygonal cells with straight anticlinal walls.

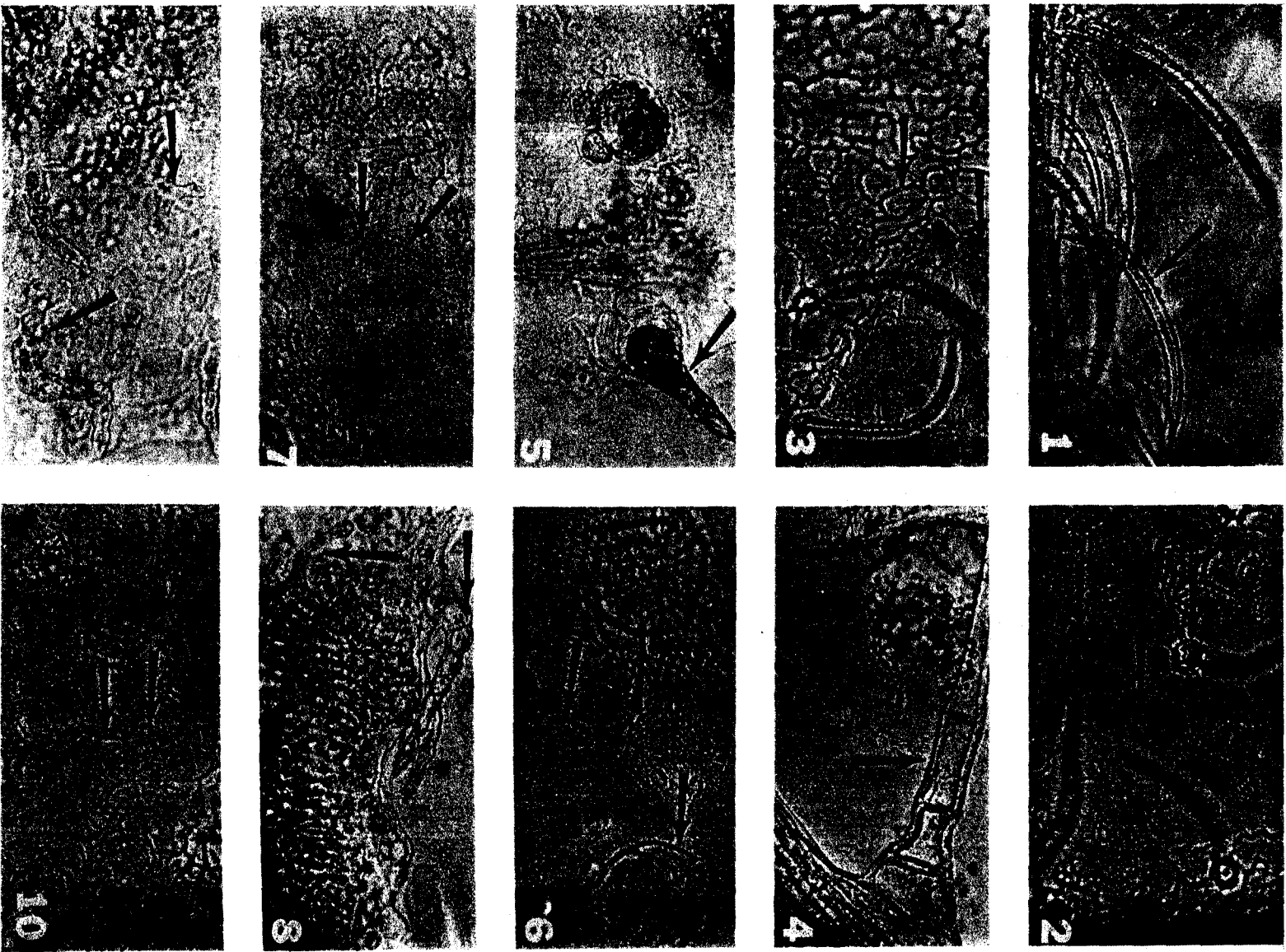


Figure 6.

Figure 7.

1. Kuhnia eupatoriodes. 125X Stem: uniseriate hairs with rounded cells tapering to a long oblong terminal cell, proximal portion moniliform.
2. Lappula spp. 125X Leaf epidermis: dentiform, unicellular hairs.
3. Lappula spp. 125X Leaf epidermis: dentiform, unicellular hairs; circular base; wavy anticlinal walls; epidermal cells oriented horizontally.
4. Lappula spp. 125X Leaf epidermis: whorled base of hair.
5. Lappula spp. 125X Leaf epidermis: anomocytic stomata; wavy anticlinal walls; epidermal cells oriented horizontally.
6. Lappula spp. 125X Stem epidermis: rectangular cells oriented horizontally.
7. Lepidium densiflorum. 125X Leaf: large oblong, papillose, papillae.
8. Lepidium densiflorum. 125X Leaf: conical, papillose, papillae.
9. Lepidium densiflorum. 125X Leaf epidermis: circular base of papillae; diacytic stomata; stomata grouped with larger cells between groups; semi-wavy anticlinal walls.
10. Lepidium densiflorum. 125X Stem: papillose, papillae.



Figure 7.

Figure 8.

1. Liatris punctata. 125X Leaf: cuticle papillae.
2. Liatris punctata. 125X Leaf epidermis: cuticle papillae.
3. Liatris punctata. 125X Leaf epidermis: surface gland.
4. Liatris punctata. 125X Leaf epidermis: anomocytic to anisocytic stomata; irregular cells with semi-wavy anticlinal walls.
5. Linum rigidum. 125X Leaf: multicellular glandular hairs.
6. Linum rigidum. 125X Leaf: cuticle papillae.
7. Linum rigidum. 125X Leaf epidermis: paracytic stomata; polygonal cells with straight walls.
8. Linum rigidum. 125X Stem epidermis: paracytic stomata; polygonal, often rectangular, cells oriented horizontally.
9. Linum rigidum. 125X Stem epidermis: papillae.
10. Mirabilis linearis. 125X Leaf: uniseriate hairs with oblong cells, terminal cell bulbous; raphides.



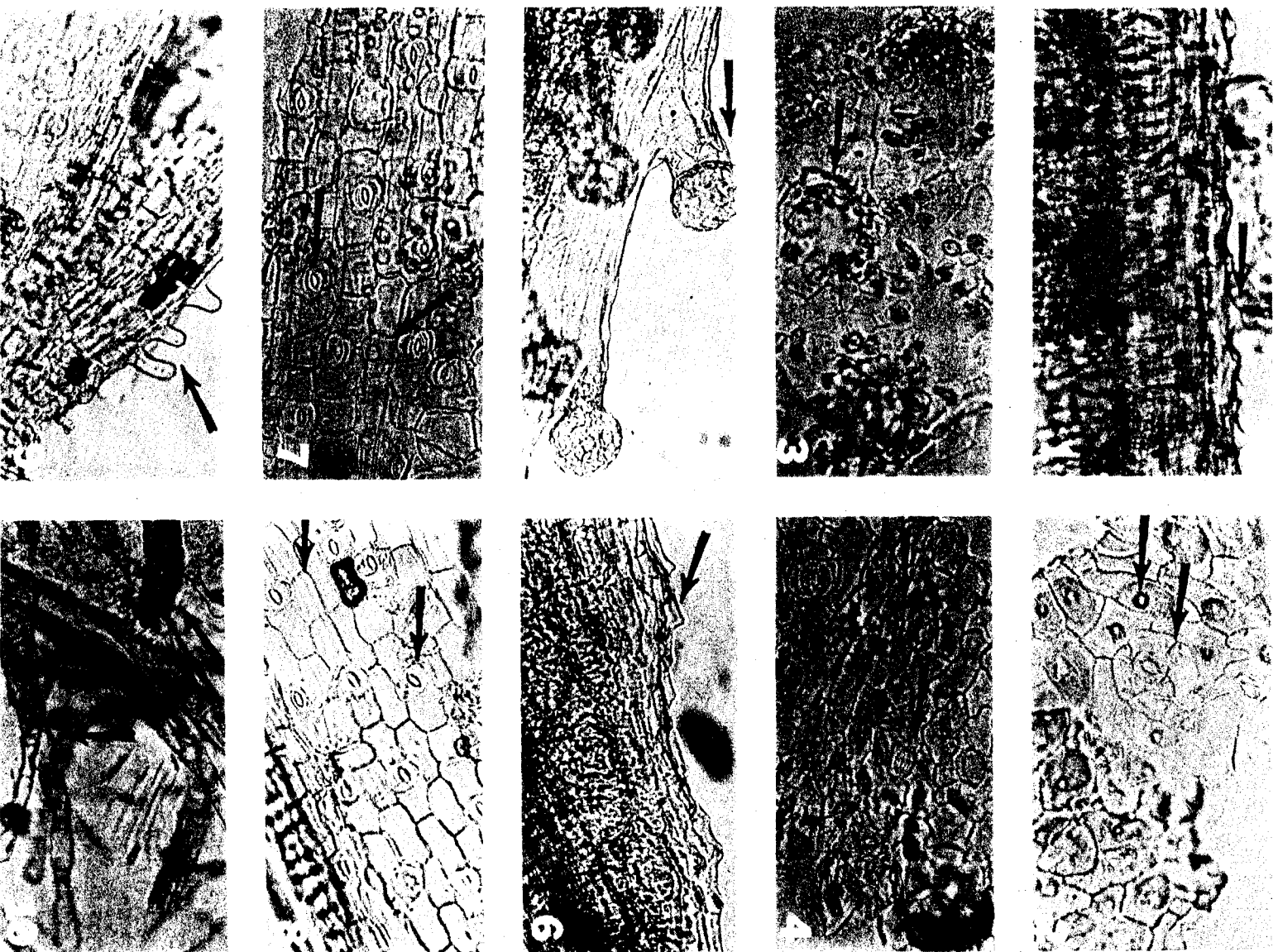


Figure 8.

Figure 9.

1. Mirabilis linearis. 125X Leaf: uniseriate hairs with oblong cells, terminal cell bulbous.
2. Mirabilis linearis. 125X Leaf epidermis: modified anisocytic stomata; polygonal cells with straight anticlinal walls; black tinge to cuticle.
3. Mirabilis linearis. 125X Stem epidermis: uniseriate hairs with oblong cells, terminal cell bulbous; rectangular cells oriented horizontally.
4. Monolepis nuttalliana. 125X Leaf epidermis: vesicular hairs with uniseriate stalks; small circular bases; druses.
5. Monolepis nuttalliana. 125X Leaf epidermis: oval cells; anomocytic stomata.
6. Oenothera albicaulis. 125X Leaf: dentiform, unicellular hair.
7. Oenothera albicaulis. 125X Leaf: dentiform, unicellular hair; slender, cylindrical, unicellular hairs; raphides.
8. Oenothera albicaulis. 125X Leaf epidermis: small, circular bases of cylindrical hairs; anomocytic stomata; oval cells with straight to semi-wavy anticlinal walls.
9. Oenothera albicaulis. 125X Stem: cylindrical, unicellular hairs.
10. Opuntia polyacantha. 125X Leaf: uniseriate hairs with oblong cells tapering to a rounded tip; hairs very long with cells often impregnated, mesh pattern on cell walls.

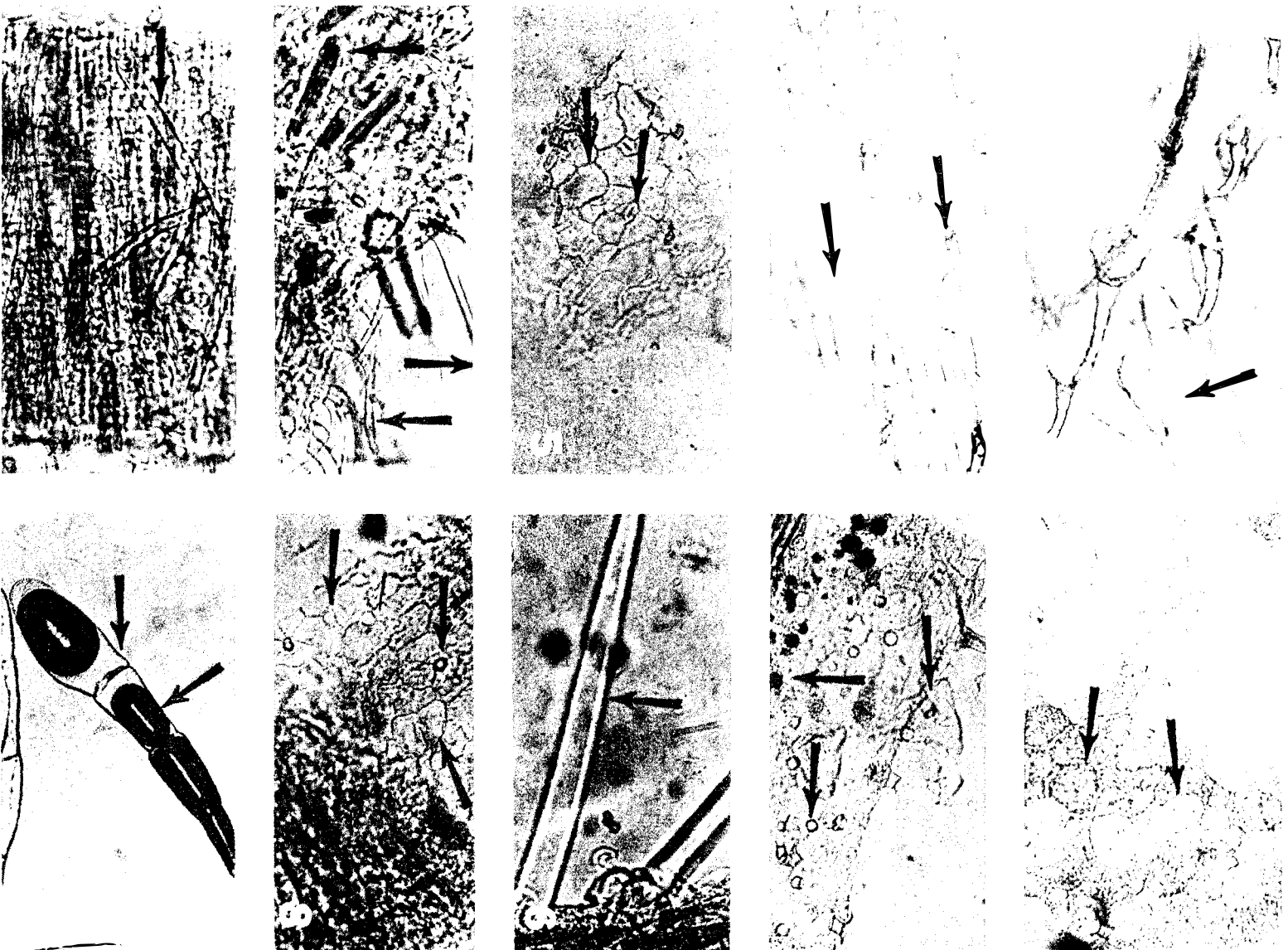


Figure 9.

Figure 10.

1. Opuntia polyacantha. 125X Leaf epidermis: small, cuticle, papillae; paracytic to acinocytic stomata; polygonal to oval cells with straight to semi-wavy anticlinal walls.
2. Opuntia polyacantha. 125X Leaf epidermis: druses.
3. Oxytropis spp. 125X Leaf epidermis: T-shaped, unicellular, papillose hairs; raised, circular base.
4. Oxytropis spp. 125X Leaf epidermis: anisocytic stomata; polygonal cells with straight anticlinal walls with prominent pitting.
5. Oxytropis spp. 125X Stem epidermis: T-shaped, papillose, unicellular hairs; paracytic stomata; irregular to rectangular cells oriented horizontally.
6. Plantago patagonica. 125X Leaf epidermis: uniseriate hairs with rectangular cells tapering to a pointed tip, cells of hair thin and elongated.
7. Plantago patagonica. 125X Leaf epidermis: raised, circular bases of uniseriate hairs; glandular hairs with two celled globose distal end and one to two celled stalk.
8. Plantago patagonica. 125X Leaf epidermis: anisocytic to diacytic stomata; irregular cells with wavy to semi-wavy anticlinal walls; cells oriented horizontally.
9. Plantago spinulosa. 125X Leaf epidermis: raised, circular bases of uniseriate hairs.
10. Plantago spinulosa. 125X Stem epidermis: raised, circular bases of uniseriate hairs; narrowed rectangular cells oriented horizontally.

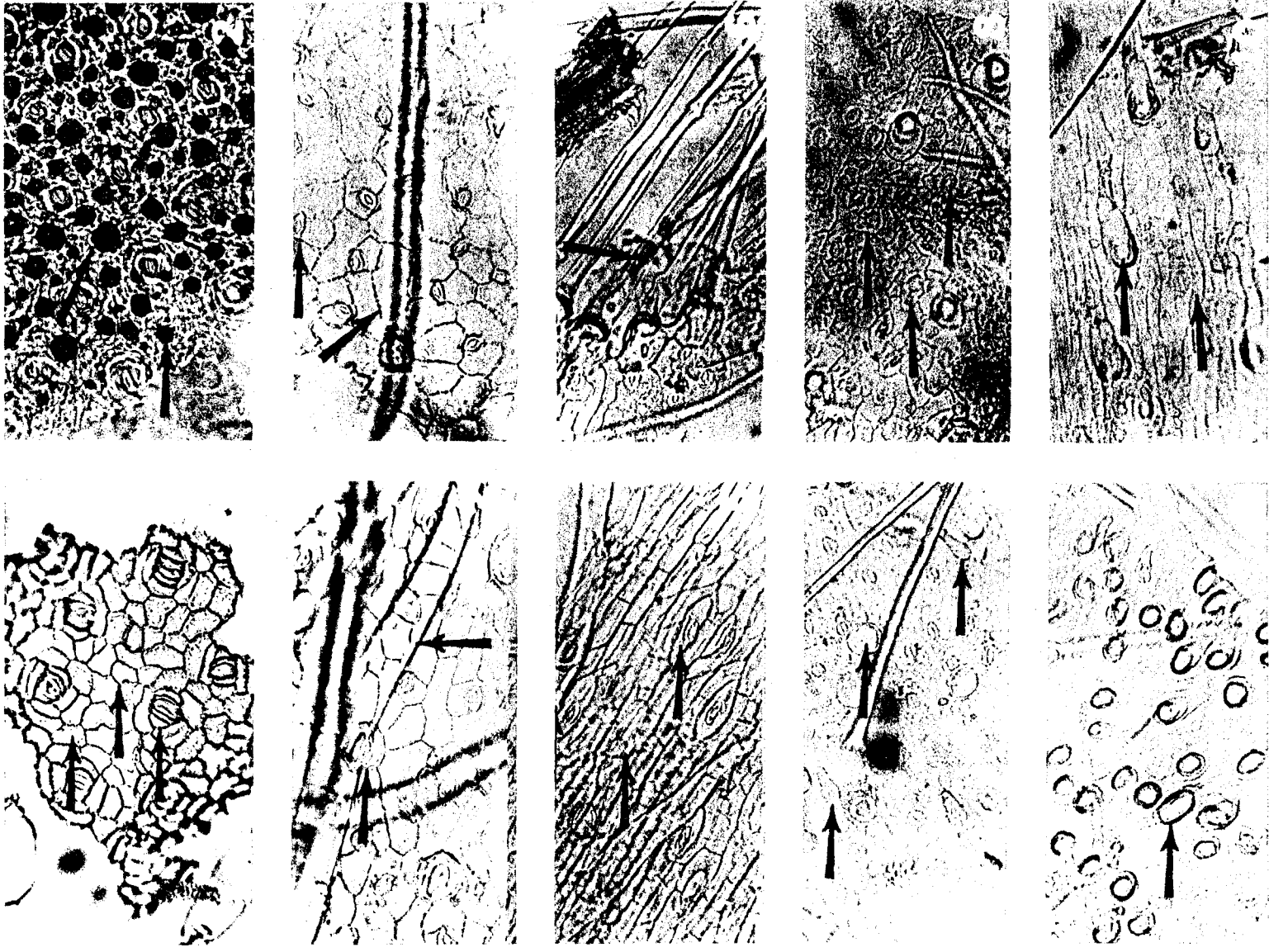


Figure 10.

Figure 11.

1. Polygala alba. 125X Leaf: bullate surface.
2. Polygala alba. 125X Leaf epidermis: small, cylindrical, unicellular hairs.
3. Polygala alba. 125X Leaf epidermis: small, cylindrical, unicellular hairs; anomocytic stomata; irregular cells with wavy anticlinal walls.
4. Polygala alba. 125X Stem epidermis: paracytic stomata; narrow rectangular cells oriented horizontally.
5. Polygala verticillata. 125X Leaf: bullate surface.
6. Polygala verticillata. 125X Leaf epidermis: small, cylindrical, unicellular hairs; anomocytic stomata; irregular cells with semi-wavy anticlinal walls.
7. Polygala verticillata. 125X Leaf epidermis: anomocytic stomata; irregular cells with semi-wavy anticlinal walls.
8. Polygala verticillata. 125X Stem epidermis: small, cylindrical, unicellular hairs; paracytic or anisocytic stomata; rectangular cells oriented horizontally.
9. Polygonum aviculare. 125X Leaf: glabrous, bullate surface; druses.
10. Polygonum aviculare. 125X Leaf epidermis: anisocytic to paracytic stomata; polygonal cells with straight anticlinal walls; ridged cuticle.

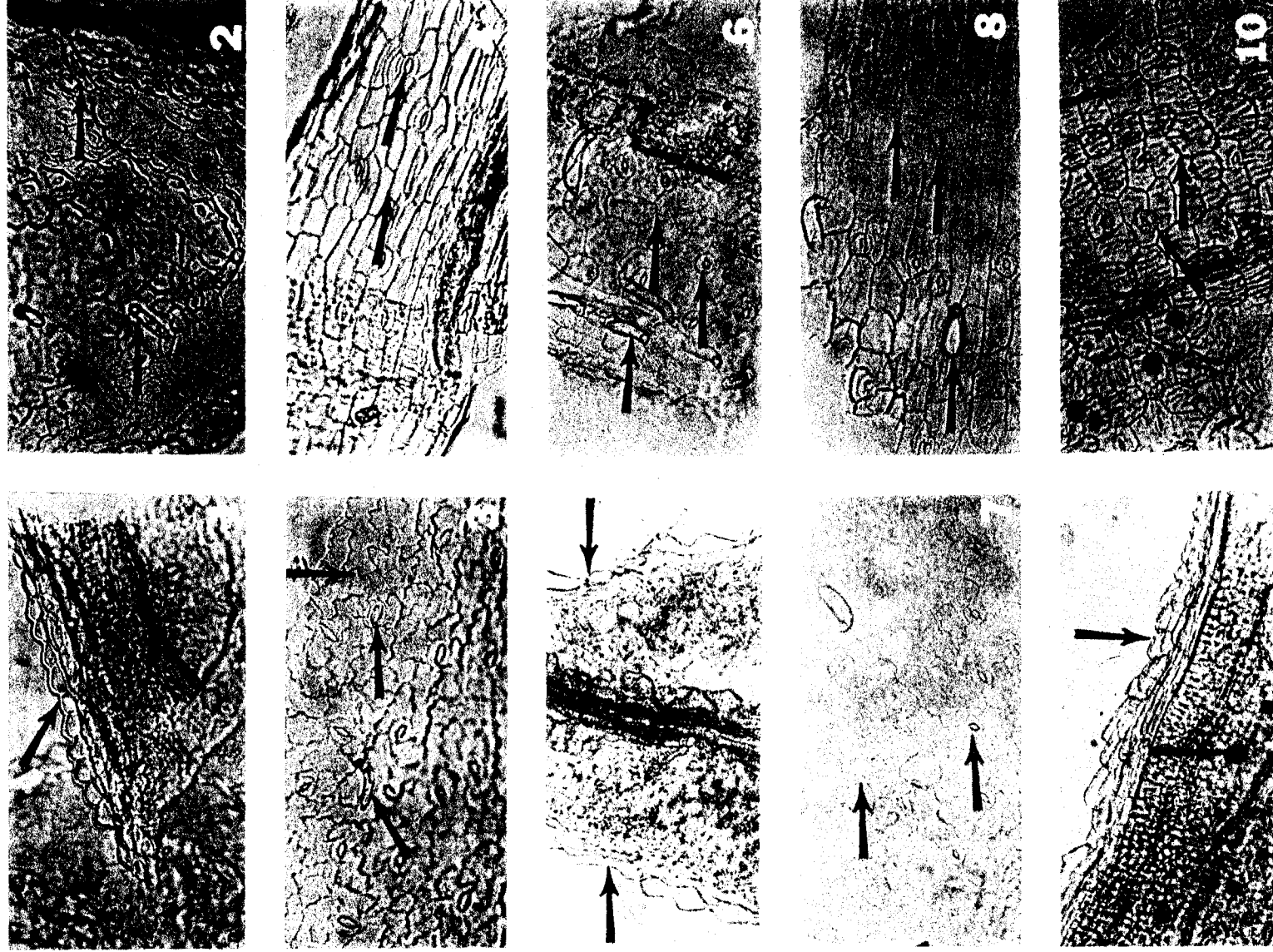


Figure 11.

Figure 12.

1. Polygonum aviculare. 125X Stem epidermis: paracytic stomata; polygonal cells.
2. Psoralea argophylla. 125X Stem: T-shaped, papillose, unicellular hairs.
3. Psoralea argophylla. 125X Leaf epidermis: T-shaped, papillose, unicellular hairs; raised, circular base; anisocytic to anomocytic stomata; oval to polygonal cells.
4. Psoralea cuspidata. 125X Leaf: dentiform hairs; raised circular bases.
5. Psoralea cuspidata. 125X Leaf epidermis: small glandular hairs.
6. Psoralea cuspidata. 125X Leaf epidermis: surface glands.
7. Psoralea cuspidata. 125X Leaf epidermis: paracytic stomata; polygonal shaped cells with semi-wavy to straight anticlinal walls.
8. Psoralea tenuiflora. 125X Stem: dentiform, unicellular hairs.
9. Psoralea tenuiflora. 125X Leaf epidermis: small glandular hairs; dentiform, unicellular hairs.
10. Psoralea tenuiflora. 125X Leaf epidermis: surface glands; paracytic stomata; polygonal cells with straight to semi-wavy anticlinal walls.



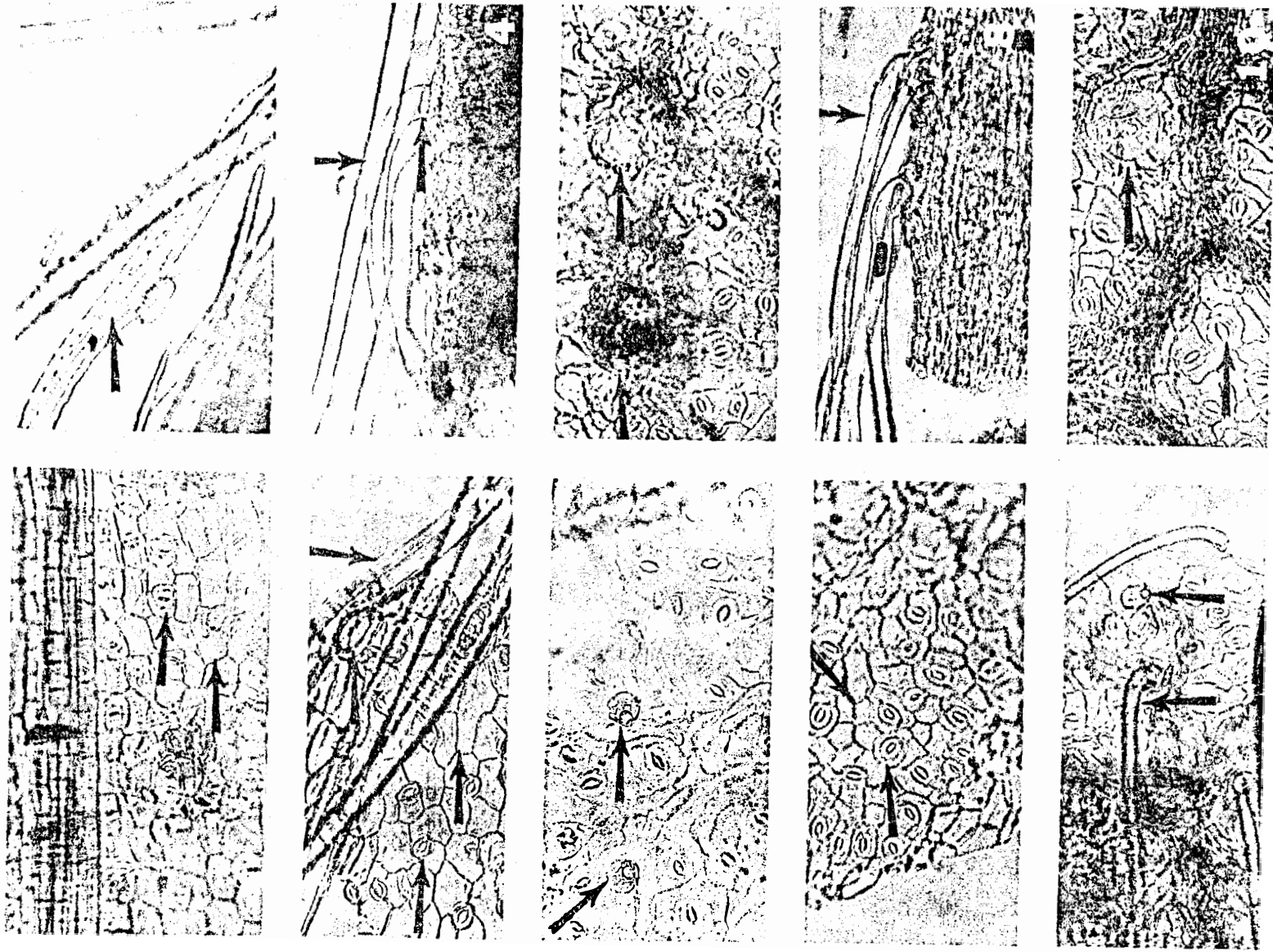


Figure 12.

Figure 13.

1. Psoralea tenuiflora. 125X Stem epidermis: paracytic stomata; irregular cells with straight anticlinal walls.
2. Ratibida columnifera. 125X Leaf: uniseriate hairs with rectangular cells tapering to a pointed tip.
3. Ratibida columnifera. 125X Leaf epidermis: whorled bases of uniseriate hairs.
4. Ratibida columnifera. 125X Leaf epidermis: anomocytic stomata; oval cells with semi-wavy anticlinal walls.
5. Ratibida columnifera. 125X Leaf epidermis: anomocytic stomata; oval cells with semi-wavy anticlinal walls.
6. Ratibida columnifera. 125X Stem epidermis: whorled base of uniseriate hair; irregular to rectangular cells with straight anticlinal walls, oriented horizontally.
7. Salsola kali. 125X Leaf epidermis: oblong papillae; druses.
8. Salsola kali. 125X Leaf epidermis: conical papillae.
9. Salsola kali. 125X Leaf epidermis: paracytic stomata; hexagonal cells with straight anticlinal walls.
10. Salsola kali. 125X Stem epidermis: paracytic stomata; rectangular, elongated cells with straight anticlinal walls, oriented horizontally.

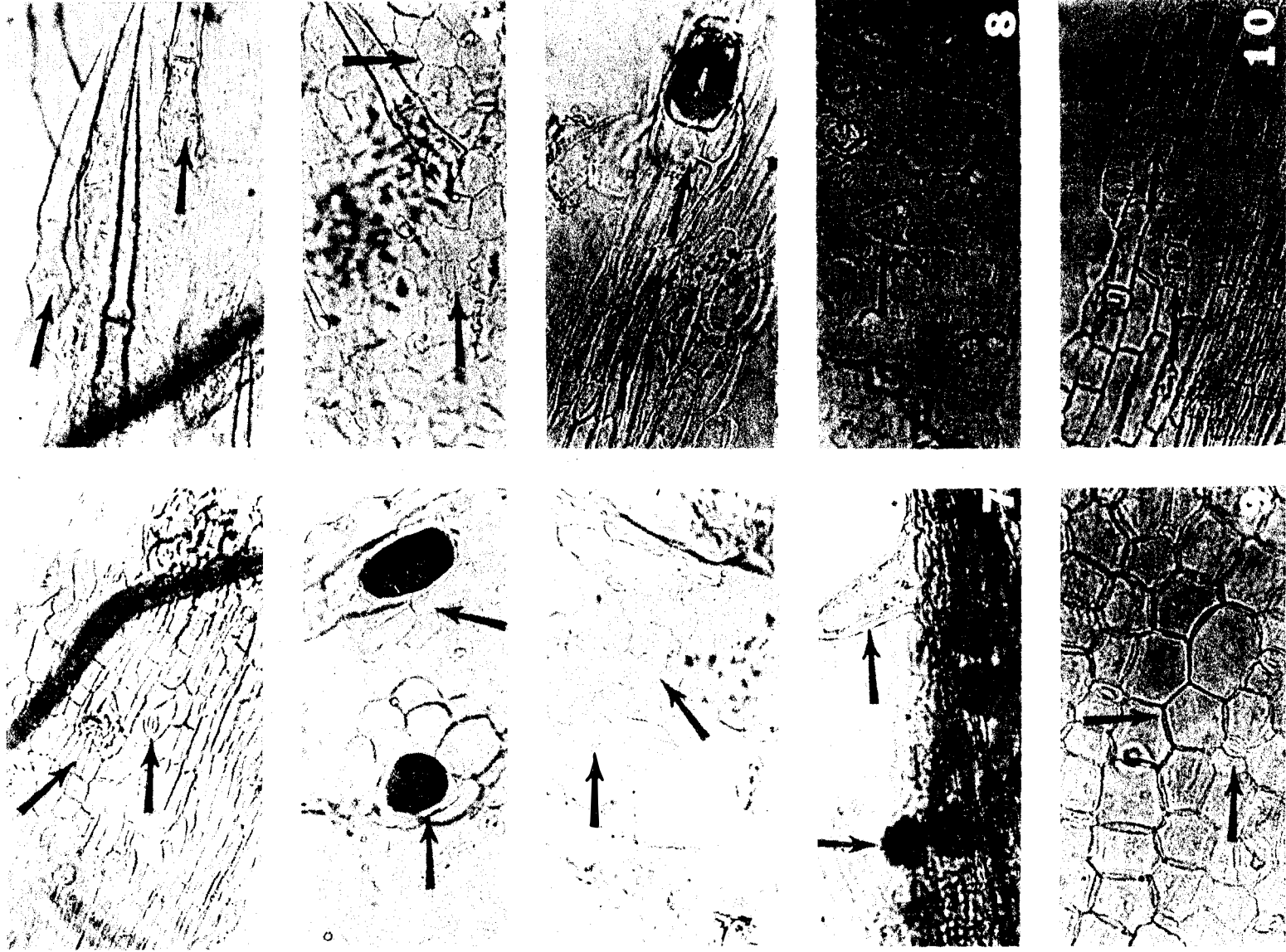


Figure 13.

Figure 14.

1. Salvia reflexa. 125X Leaf: uniseriate hairs with oblong cells tapering to a rounded tip.
2. Salvia reflexa. 125X Leaf epidermis: bristles with pointed tips.
3. Salvia reflexa. 125X Leaf epidermis: glandular hairs with four-celled terminal bulb.
4. Salvia reflexa. 125X Leaf epidermis: anisocytic stomata; irregular cells with wavy anticlinal walls; small, solitary, prismatic crystals.
5. Salvia reflexa. 125X Stem: uniseriate hairs with oblong cells tapering to a rounded tip.
6. Solanum rostratum. 125X Leaf: tufted to candelabra hair.
7. Solanum rostratum. 125X Leaf: rosette base; druses.
8. Solanum rostratum. 125X Leaf: multicellular glandular hairs.
9. Solanum triflorum. 125X Leaf: papillose, uniseriate hair with oblong cells tapering to a rounded tip.
10. Solanum triflorum. 125X Leaf epidermis: papillose, uniseriate hairs with oblong cells tapering to a rounded tip.

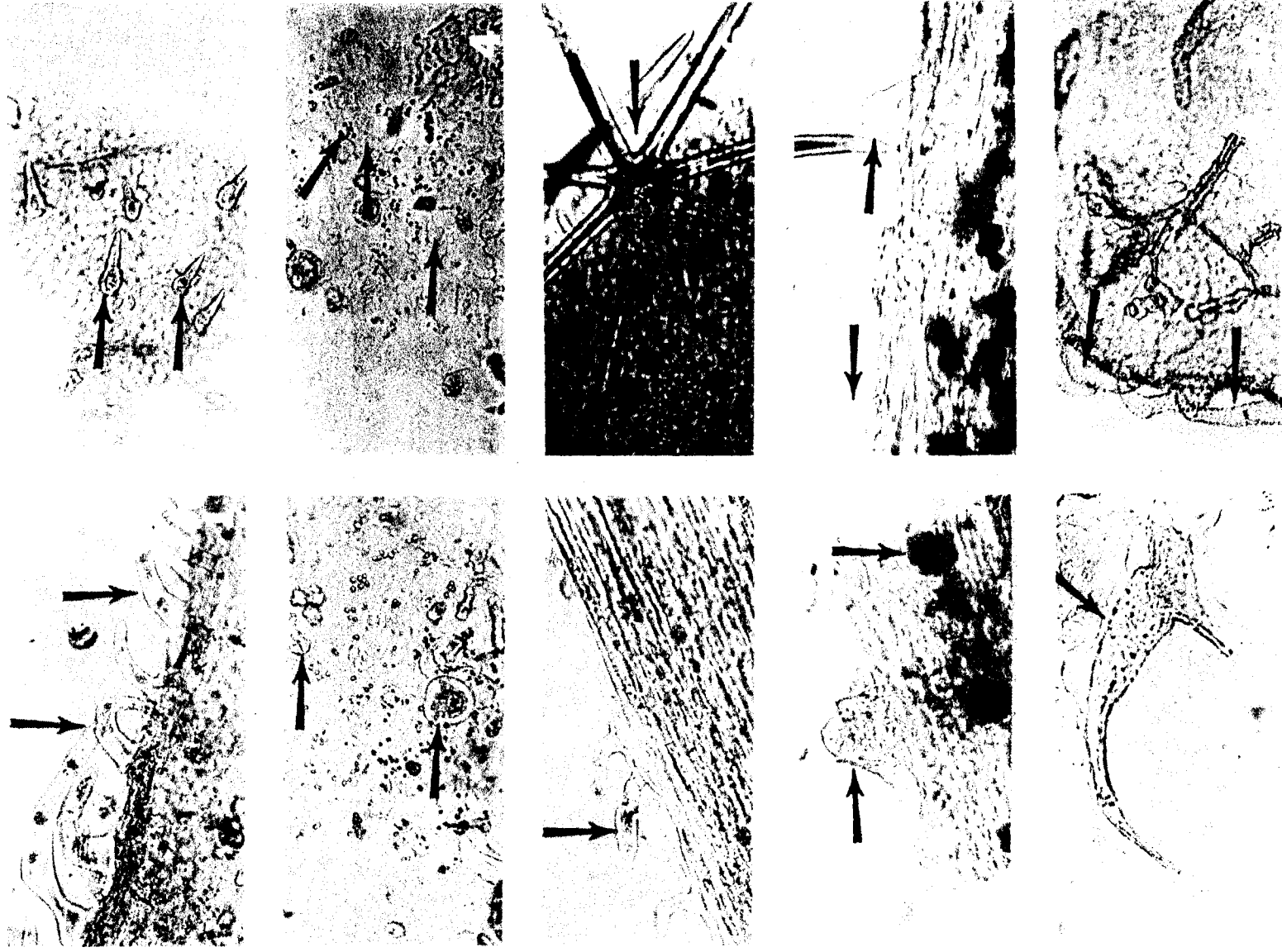


Figure 14.

Figure 15.

1. Solanum triflorum. 125X Leaf epidermis: multicellular, glandular hairs with unicellular stalk and multicellular globose distal end.
2. Solanum triflorum. 125X Leaf epidermis: anomocytic to anisocytic stomata; irregular cells with wavy to semi-wavy anticlinal walls.
3. Solanum triflorum. 125X Stem: papillose, uniseriate hairs with oblong cells tapering to a rounded tip.
4. Sphaeralcea coccinea. 125X Leaf epidermis: stellate hairs.
5. Sphaeralcea coccinea. 125X Leaf epidermis: rosette base of stellate hair.
6. Sphaeralcea coccinea. 125X Leaf epidermis: druses, anisocytic stomata.
7. Sphaeralcea coccinea. 125X Stem epidermis; rosette bases of stellate hairs.
8. Sphaeralcea coccinea. 125X Stem: rosette bases of stellate hair.
9. Taraxacum officinale. 125X Leaf margin: glabrous, smooth margin.
10. Taraxacum officinale. 125X Leaf epidermis: anisocytic to anomocytic stomata; irregular cells with wavy anticlinal walls.

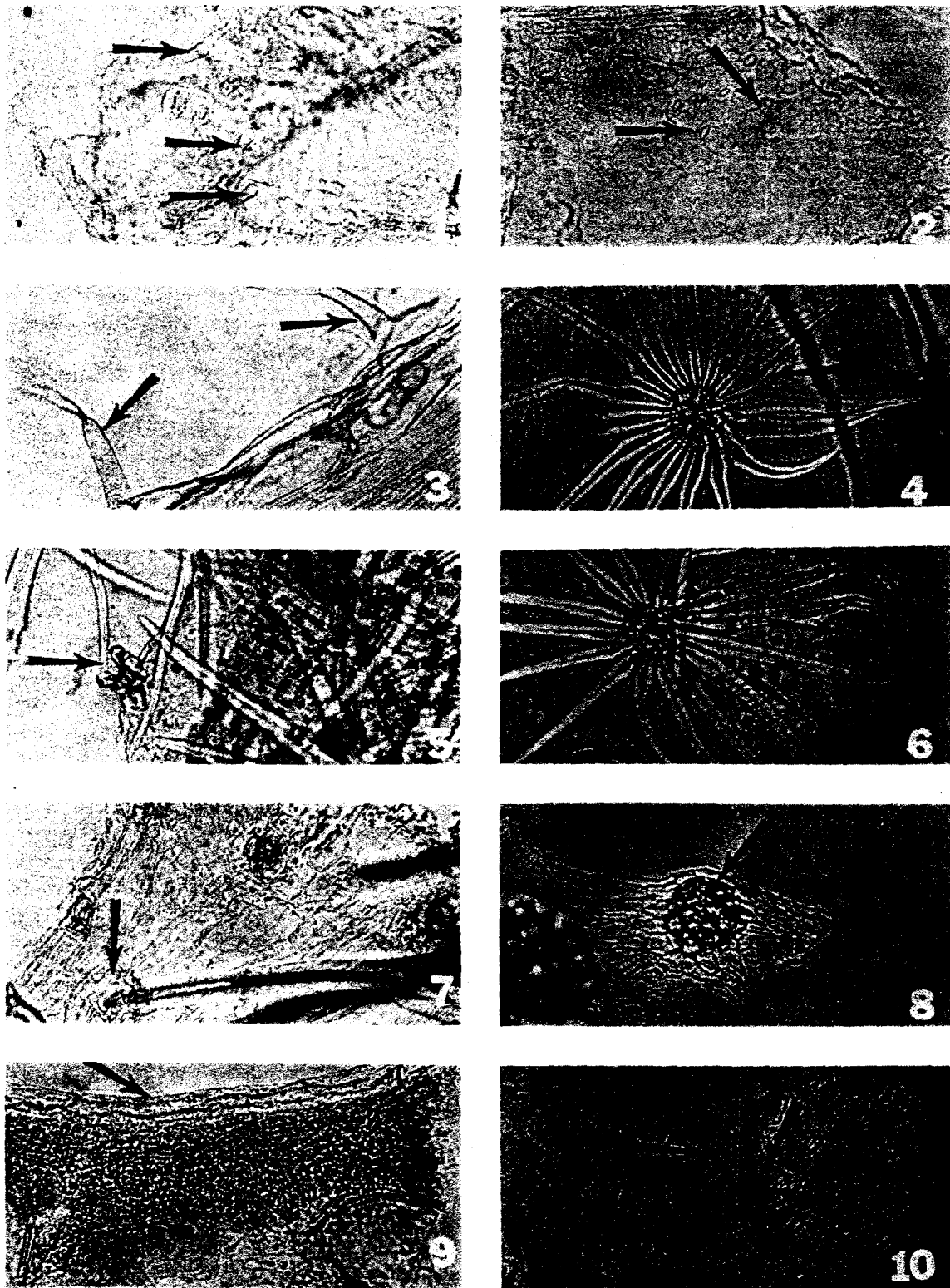


Figure 15.

Figure 16.

1. Taraxacum officinale. 125X Leaf epidermis: anisocytic to anomocytic stomata; irregular cells with wavy anticlinal walls.
2. Verbena bracteata. 125X Leaf: dentiform, unicellular hairs.
3. Verbena bracteata. 125X Leaf epidermis: whorled bases of dentiform hairs; oval cells with semi-wavy to straight anticlinal walls; anomocytic stomata.
4. Verbena bracteata. 125X Leaf epidermis: whorled bases of dentiform hairs; irregular cells with wavy anticlinal walls; anomocytic stomata.
5. Verbena bracteata. 125X Stem epidermis: whorled bases of dentiform hairs; modified anomocytic to acinocytic stomata.
6. Verbena bracteata. 125X Stem epidermis: dentiform hairs; rectangular cells oriented horizontally.
7. Viola nuttallii. 125X Leaf epidermis: oblong, papillose, papillae.
8. Viola nuttallii. 125X Leaf epidermis: conical, papillose, papillae.
9. Viola nuttallii. 125X Leaf epidermis: anisocytic stomata; irregular cells with wavy anticlinal walls.
10. Viola nuttallii. 125X Stem epidermis: conical to oblong papillae; rectangular cells oriented horizontally.



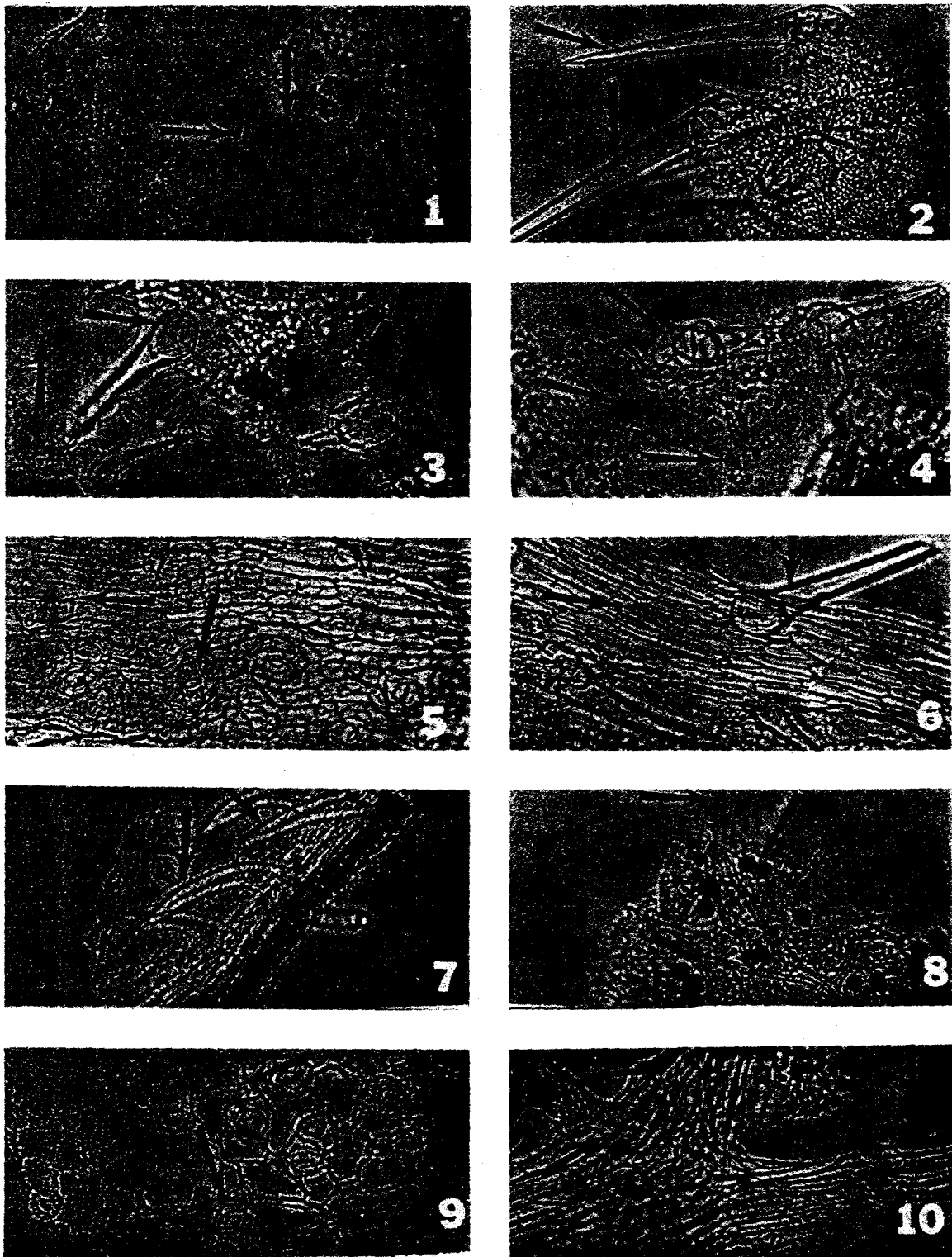


Figure 16.

Figure 17.

1. Agropyron smithii. 125X Leaf epidermis: intercostal and costal regions.
2. Agropyron smithii. 400X Leaf epidermis, intercostal region: stomata with low-dome-shaped subsidiary cells; long cells with thick, sinuous walls.
3. Agropyron smithii. 400X Leaf epidermis, intercostal region: short cells in pairs, circular cell fitting inside tall and narrow cell, silica body thin and curved contained inside circular cell.
4. Agropyron smithii. 400X Leaf epidermis, costal region: short cells in pairs, circular, pitted cell and tall and narrow cell with thin, curved silica body inside tall cell.
5. Agropyron smithii. 400X Leaf epidermis, costal region: short cells in singles, circular, pitted cells.
6. Agropyron smithii. 400X Leaf epidermis, costal region: prickles with rounded bases.
7. Aristida longiseta. 125X Leaf epidermis: intercostal and costal regions.
8. Aristida longiseta. 400X Leaf epidermis, intercostal region: stomata with triangular subsidiary cells.
9. Aristida fendleriana. 400X Leaf epidermis, intercostal region: short cells in pairs, one cell dumb-bell-shaped with close fitting silica body of similar shape, the other cell square to crescent-shaped.
10. Aristida fendleriana. 400X Leaf epidermis, intercostal region: microhair with long, narrow proximal cell and shorter, but narrowed, distal cell tapering to rounded apex.

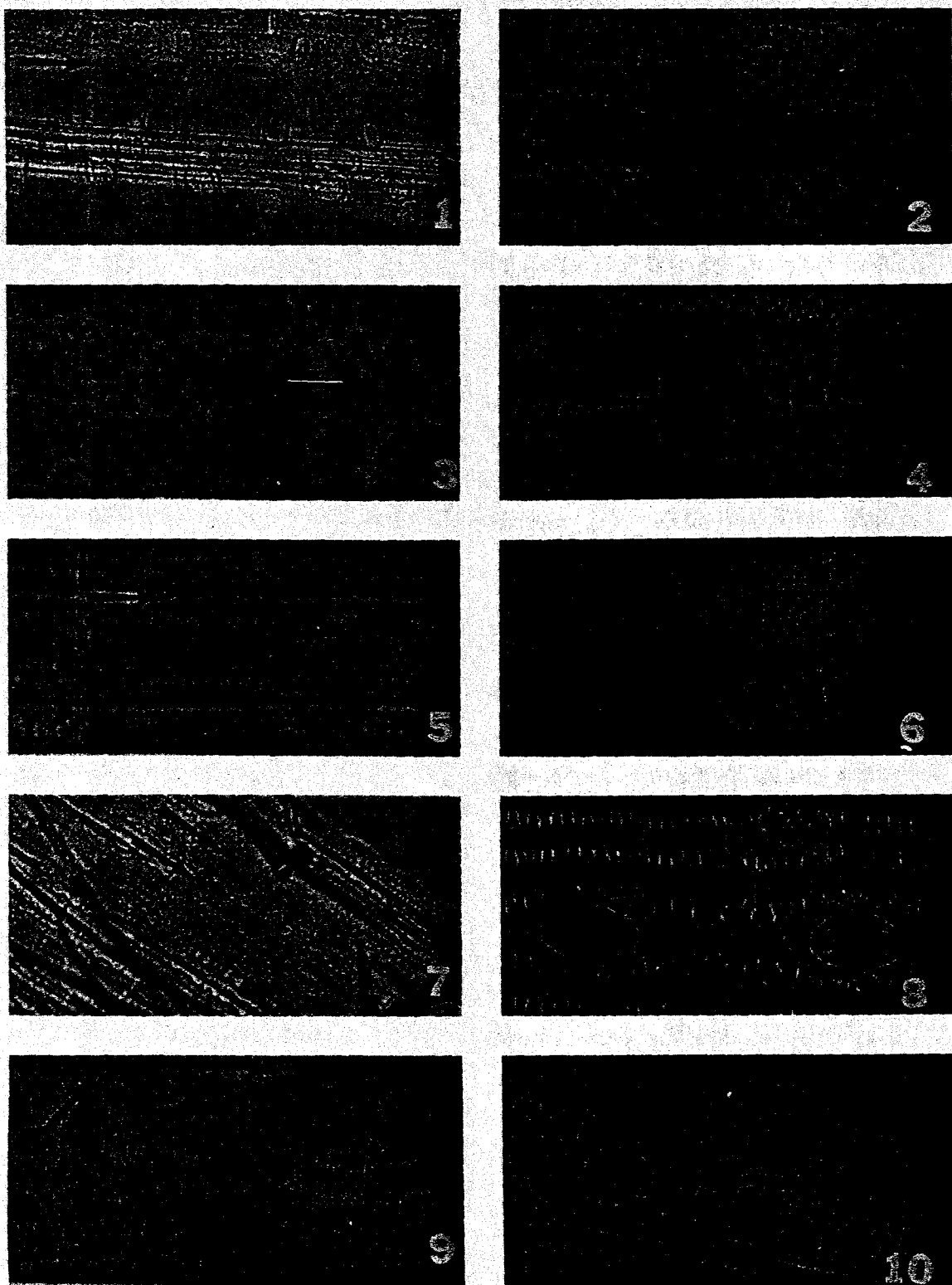


Figure 17.

Figure 18.

1. Aristida longiseta. 400X Leaf epidermis, costal region: short cells in singles, dumb-bell-shaped cell with similar shaped silica body.
2. Aristida longiseta. 400X Sheath epidermis: short cells in pairs, one cell oval with close fitting silica body of same shape, other cell tall, oval cell; small macrohairs.
3. Aristida longiseta. 400X Sheath epidermis: short cells in singles, cell oval with similar shaped silica body; small macrohairs.
4. Bouteloua gracilis. 125X Leaf epidermis: intercostal and costal regions.
5. Bouteloua gracilis. 400X Leaf epidermis, intercostal region: stomata with triangular subsidiary cells; short cells in pairs, both cells tall and narrow with one containing similar shaped silica body.
6. Bouteloua gracilis. 400X Leaf epidermis, intercostal region: short cells in pairs, both cells tall and narrow with one cell containing similar shaped silica body; microhair, proximal cell tapering, distal cell, not tapering, elongated hemispherical cell.
7. Bouteloua gracilis. 400X Leaf epidermis, intercostal region: microhair, proximal cell tapering, distal cell, not tapering, elongated hemispherical cell.
8. Bouteloua gracilis. 400X Leaf epidermis, costal region: short cells in singles, saddle-shaped cell with silica body similar shaped.
9. Bouteloua gracilis. 400X Leaf epidermis, intercostal region: long cells with papillae.
10. Bouteloua gracilis. 400X Sheath epidermis: large area with very sinuous long cells and short cells; short cells in pairs, both cells tall and narrow with one containing similar shaped silica body.

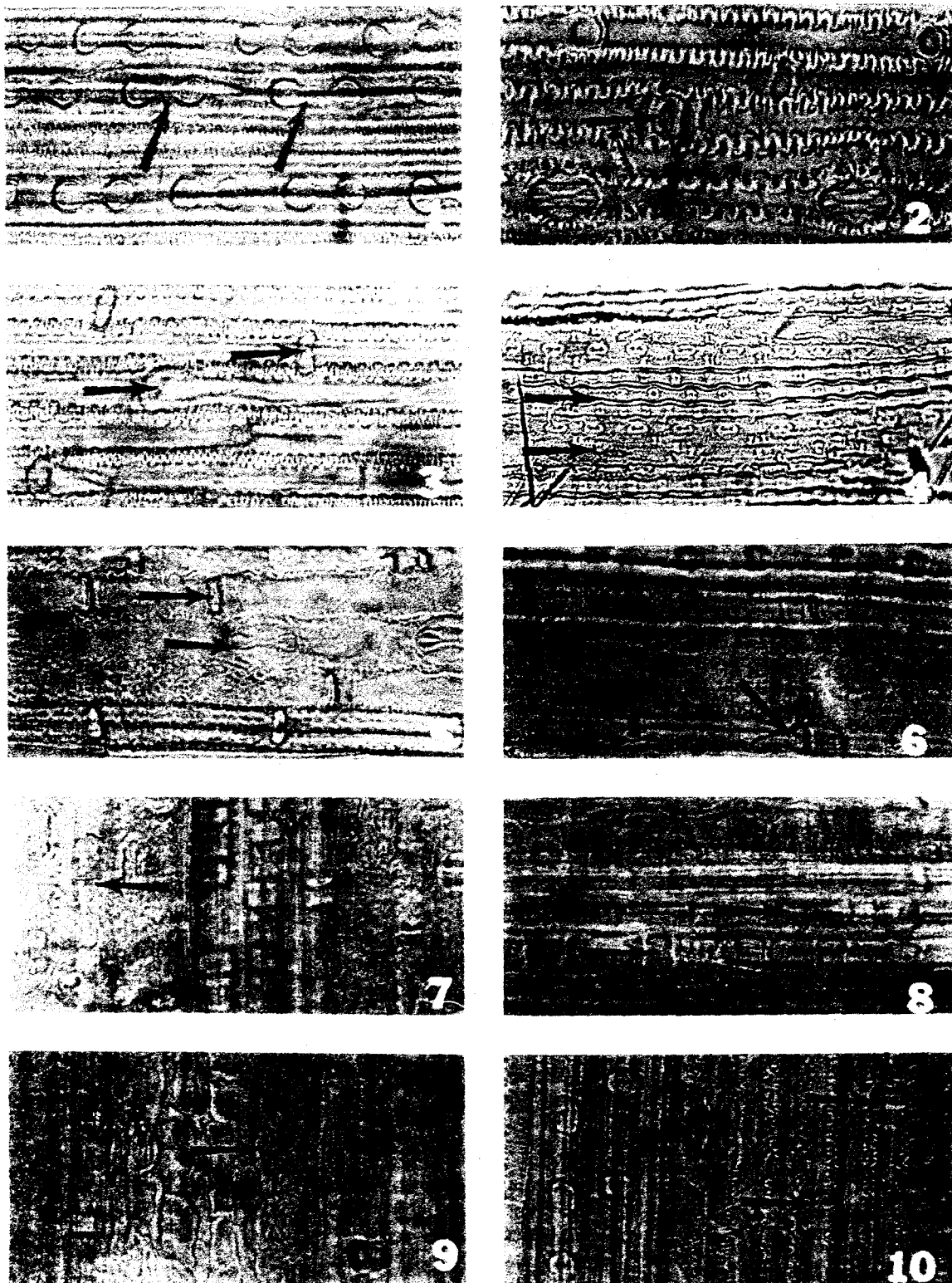


Figure 18.

Figure 19.

1. Bromus japonicus. 125X Leaf epidermis: intercostal and costal regions.
2. Bromus japonicus. 400X Leaf epidermis, intercostal region: stomata with parallel-sided subsidiary cells; short cells in pairs, one small, circular cell with thin, curved silica body, other cell square to rectangular.
3. Bromus japonicus. 400X Leaf epidermis, intercostal region: short cells in singles, circular, pitted cells.
4. Bromus tectorum. 400X Leaf epidermis, intercostal region: long macrohairs.
5. Bromus tectorum. 400X Leaf epidermis, costal region: short cells in singles, cells elongated horizontally with rounded ends and either smooth or sinuous sides, silica body close fitting and of similar shape as cell.
6. Bromus japonicus. 400X Leaf epidermis, costal region: short cells in singles, cells elongated horizontally with rounded ends and either smooth or sinuous sides, silica body close fitting and of similar shape as cell.
7. Bromus japonicus. 125X Sheath epidermis: intercostal and costal regions.
8. Buchloe dactyloides. 125X Leaf epidermis: intercostal and costal regions.
9. Buchloe dactyloides. 400X Leaf epidermis, intercostal region: stomata with triangular subsidiary cells; microhair.
10. Buchloe dactyloides. 400X Leaf epidermis, intercostal region: short cells in pairs, one cell smaller and square containing silica body with C- to J-shaped, other cell tall and narrow.

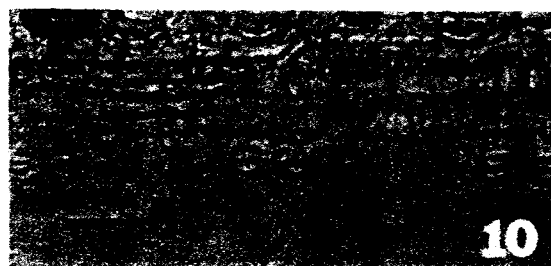
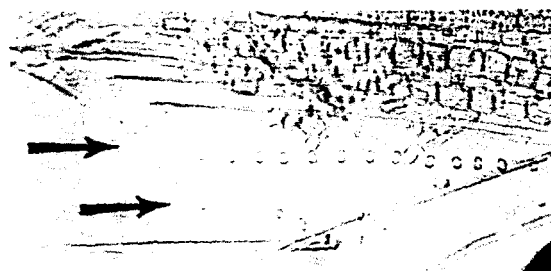
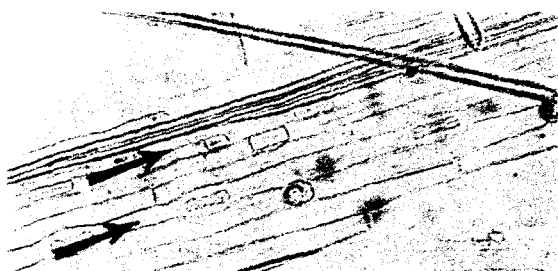
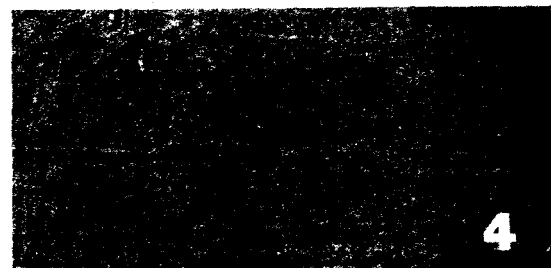
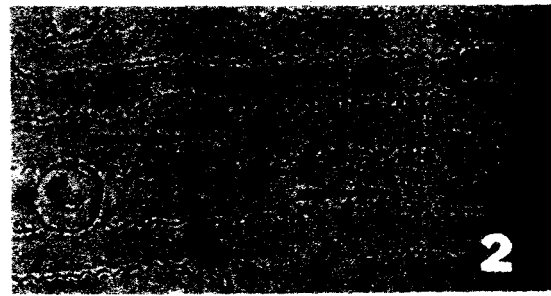
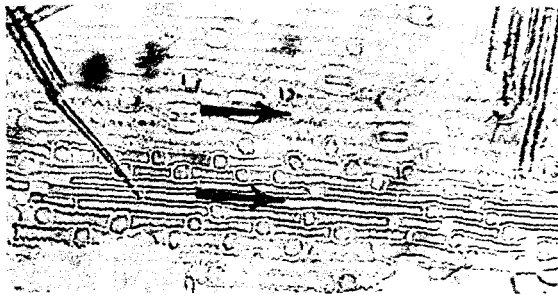


Figure 19.

Figure 20.

1. Buchloe dactyloides. 400X Leaf epidermis, intercostal region: microhair, basal cell tapering and more than four times the length of the distal cell, distal cell hemispherical and not elongated.
2. Buchloe dactyloides. 400X Leaf epidermis, intercostal region: macrohair base in cushion of irregular shaped epidermal cells.
3. Buchloe dactyloides. 400X Leaf epidermis, costal region: short cells in singles, saddle-shaped with similar shaped silica body.
4. Buchloe dactyloides. 400X Leaf epidermis, intercostal region: papillae on long cells.
5. Buchloe dactyloides. 400X Sheath epidermis: large section with short cells in pairs with one cell saddle-shaped with similar shaped silica body, other cell crescent-shaped.
6. Carex filifolia. 125X Leaf epidermis: intercostal and costal regions.
7. Carex filifolia. 400X Leaf epidermis: stomata with low-dome-shaped to triangular subsidiary cells; short cells absent.
8. Carex filifolia. 400X Leaf epidermis: long cells with sinuous walls.
9. Festuca octoflora. 125X Leaf epidermis: intercostal and costal regions.
10. Festuca octoflora. 400X Leaf epidermis, intercostal region: stomata with parallel-sided subsidiary cells; short cells in pairs with one smaller, circular cell fitting into tall and narrow cell, silica body thin and curved inside circular cell.



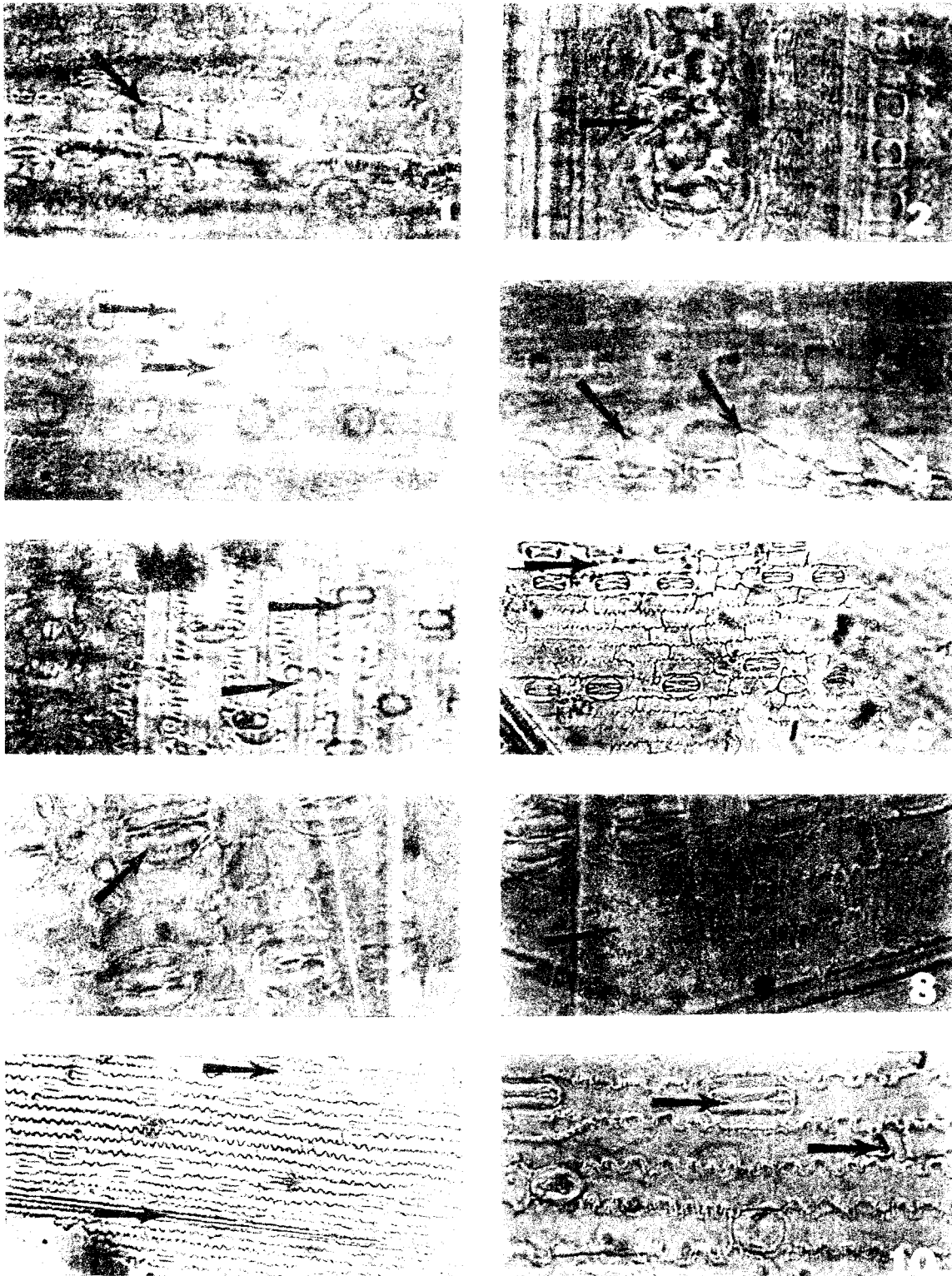


Figure 20.

Figure 21.

1. Festuca octoflora. 400X Leaf epidermis, costal region: short cells in singles, horizontally elongated cells with rounded ends, silica body close fitting with similar shape as cell.
2. Festuca octoflora. 400X Sheath epidermis: large area of short cells in pairs with one smaller, circular cell fitting into tall and narrow cell, silica body thin, curved inside circular cell.
3. Festuca octoflora. 400X Leaf epidermis, costal region: short cells in pairs, horizontally elongated cells with rounded ends, silica body close fitting with similar shape as cell, other cell square.
4. Munroa squarrosa. 125X Leaf epidermis: intercostal and costal region.
5. Munroa squarrosa. 400X Leaf epidermis, intercostal region: stomata with triangular subsidiary cells.
6. Munroa squarrosa. 400X Leaf epidermis, intercostal region: microhairs, short, with proximal and distal cells of similar length.
7. Munroa squarrosa. 400X Leaf epidermis, intercostal region: short cells in pairs, one cell cross-shaped with similar shaped silica body, other cell square to tall and narrow; prickles.
8. Munroa squarrosa. 400X Leaf epidermis, costal region: short cells in pairs, one cell cross-shaped with similar shaped silica body, other cell square to crescent-shaped; prickles.
9. Munroa squarrosa. 400X Leaf epidermis, costal region: short cells in singles, cross-shaped with similar shaped silica body.
10. Munroa squarrosa. 400X Sheath epidermis: large area with short cells in pairs, from saddle-shaped to cross-shaped with similar shaped silica body, other cell square to crescent-shaped.

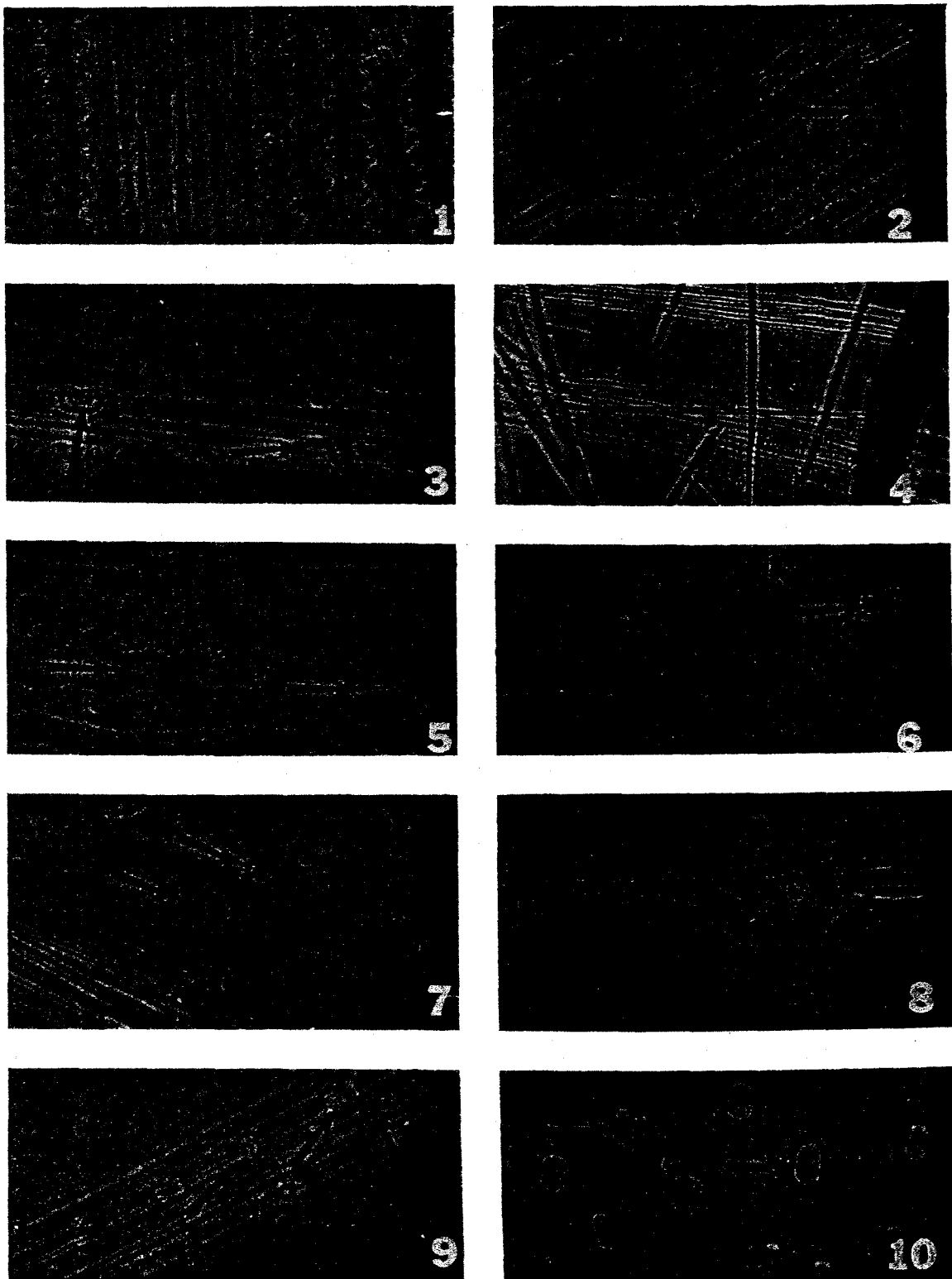


Figure 21.

Figure 22.

1. Munroa squarrosa. 400X Sheath epidermis: large area with short cells in pairs, from saddle-shaped to cross-shaped with similar shaped silica body, other cell square to crescent-shaped.
2. Schedonnardus paniculatus. 125X Leaf epidermis: intercostal and costal regions.
3. Schedonnardus paniculatus. 400X Leaf epidermis: intercostal region: stomata with triangular subsidiary cells; papillae.
4. Schedonnardus paniculatus. 400X Leaf epidermis, intercostal region: microhair, basal cell tapering, two to three times longer than distal cell, distal cell tapering with rounded apex.
5. Schedonnardus paniculatus. 400X Leaf epidermis, costal region: short cells in singles, saddle-shaped to angled with silica body angled to square.
6. Schedonnardus paniculatus. 400X Sheath epidermis: large area with short cells in singles, saddle-shaped cells with square to angled silica body.
7. Sporobolus cryptandrus. 400X Leaf epidermis: intercostal and costal regions.
8. Sporobolus cryptandrus. 400X Leaf epidermis, intercostal region: stomata with triangular subsidiary cells; microhairs, basal cell about twice the length of distal cell, distal cell tapering to extended tip.
9. Sporobolus cryptandrus. 400X Leaf epidermis, intercostal region: short cells in pairs, one cell square to tall and narrow containing silica body C- to J-shaped, other cell larger and tall and narrow.
10. Sporobolus cryptandrus. 400X Leaf epidermis, costal region: short cells generally in pairs, saddle- to cross-shaped with similar shaped silica body, other cell crescent-shaped to square.

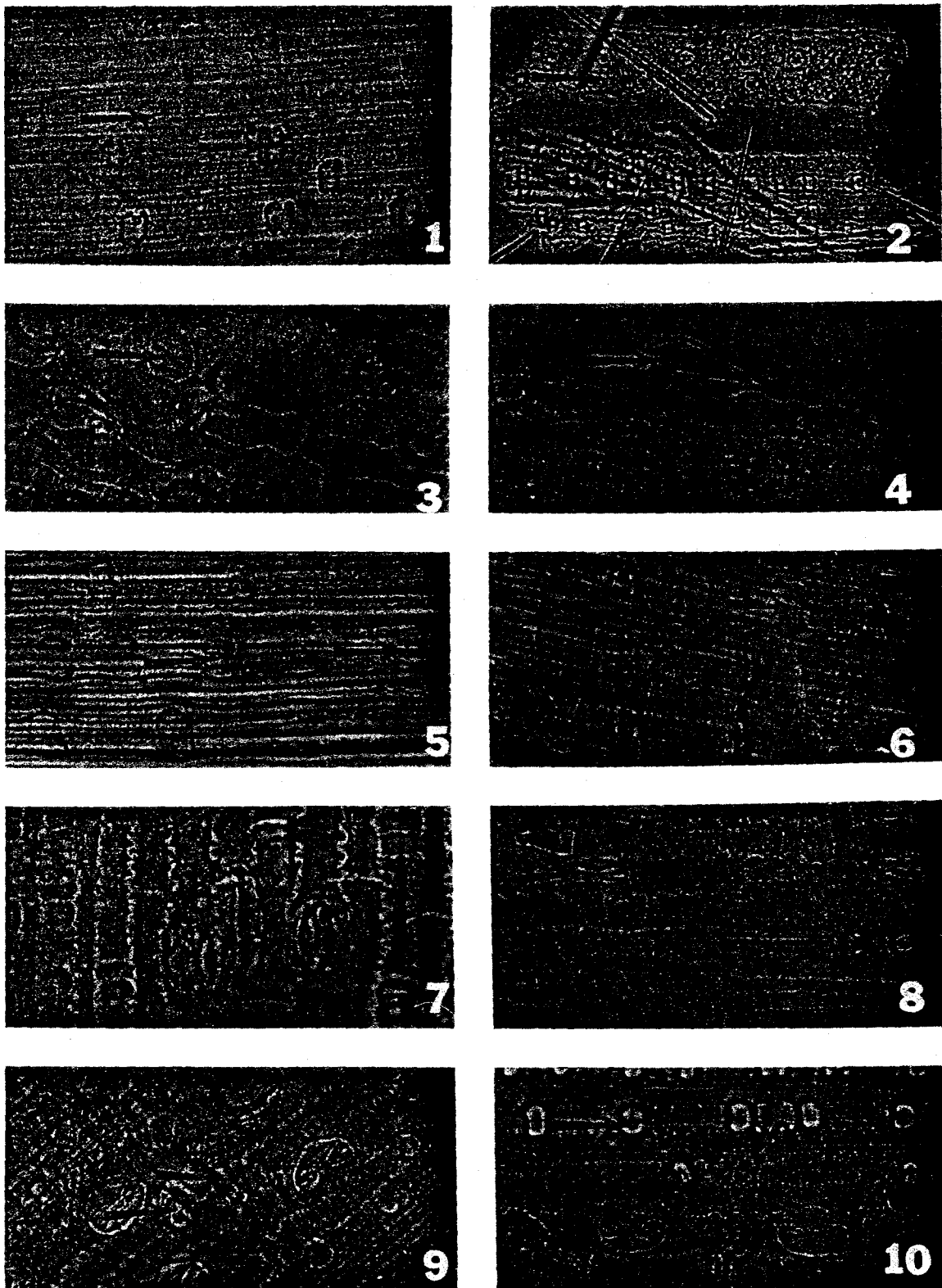


Figure 22.

Figure 23.

1. Sporobolus cryptandrus. 400X Leaf epidermis, costal region: short cells generally in pairs, cells saddle- to cross-shaped with similar shaped silica body, other cell crescent-shaped to square.
2. Sporobolus cryptandrus. 400X Leaf epidermis, costal region: short cells generally in pairs, cells saddle- to cross-shaped with similar shaped silica body, other cell crescent-shaped to square.
3. Sporobolus cryptandrus. 400X Sheath epidermis: large area with short cells in pairs, one cell saddle-shaped with similar shaped silica body, other cell crescent-shaped.
4. Sporobolus cryptandrus. 400X Sheath epidermis: large area with short cells in pairs, one cell saddle-shaped with similar shaped silica body, other cell crescent-shaped.

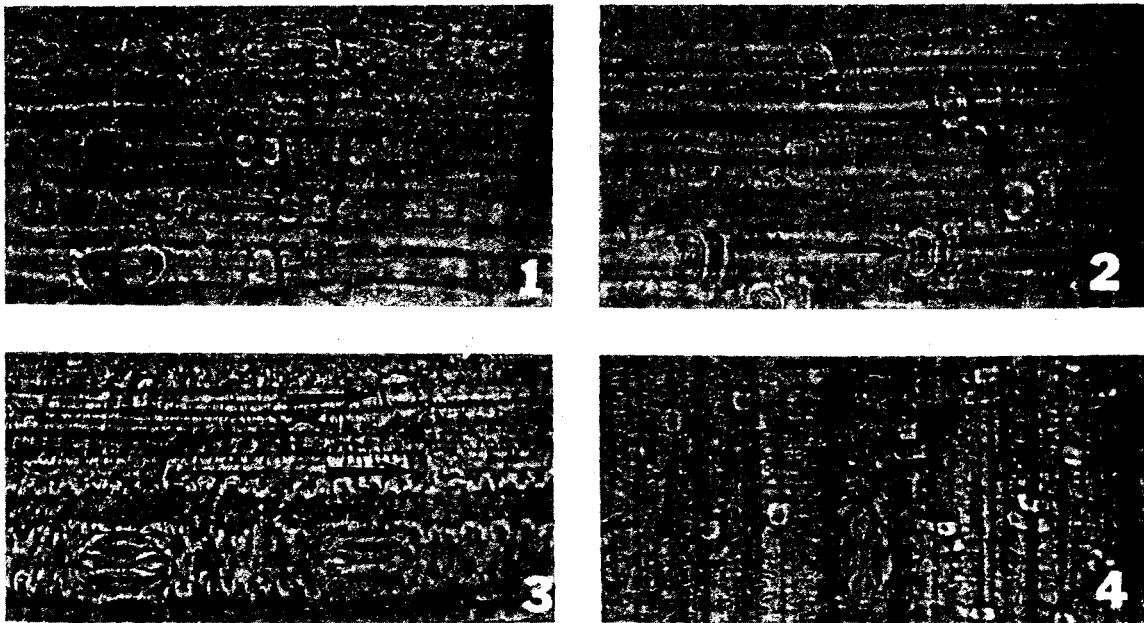


Figure 23.

### Food Habits of Prairie Dogs

A nested analysis of variance (Schultz 1955, Mendenhall 1968) showed no significant differences ( $P > 0.05$ ) in the contents of prairie dog stomachs collected from burrows among vegetative types, between vegetative types within towns, and between May and August collection periods. However contents from stomachs were significantly different between towns ( $P < 0.05$ ). The range survey showed no significant difference ( $P > 0.05$ ) in vegetation between concentric circles; but differences in vegetation were significant ( $P < 0.05$ ) between burrows, between vegetative types, between towns, and between seasons.

Seven plant species made up the major (greater than 5 percent) food items in prairie dog stomachs throughout the year (Table 1). Although food habits did not change significantly between spring and summer, a change did occur in December when pricklypear and western wheatgrass were of greater importance.

Grasses made up 65 percent of the stomach volume and forbs 34 percent. Kelso (1939) reported 62 percent grasses and 34 percent forbs with western wheatgrass (12 percent) and six weeks fescue (9 percent) as the important grasses. He did not find buffalograss, blue grama, or sedge important anytime during the year. Koford (1958), Smith (1958), and Tiletston and Lechleitner (1966) listed western wheatgrass, blue grama, and buffalograss important during the growing season. Lerwick (1974) concluded that 88 percent of the diet was composed of grasses and sedges May through September. Favorite



Table 1. Percentages of dry weight (relative density) for plant species in stomach samples of black-tailed prairie dogs collected from Town 11 and Burns Basin in 1973. Trace (tr) is less than 1 percent.

Plant species	Percent dry weight				
	December (8) <sup>a</sup>	May (40)	June-July (14)	August (56)	Annual (118)
Total grasses and sedges	57	65	74	66	65
Total forbs	43	35	25	33	34
Major Species					
<u>Agropyron smithii</u>	38	10	12	5	16
<u>Bouteloua gracilis</u>	2	9	13	11	9
<u>Buchloe dactyloides</u>	8	22	34	29	23
<u>Carex filifolia</u>	8	16	4	10	9
<u>Opuntia polyacantha</u>	32	tr	1	1	8
<u>Plantago spp.</u>	1	9	5	1	4
<u>Sphaeralcea coccinea</u>	11	21	15	26	18
<sup>a</sup> sample size in parentheses					

Table 1. Continued. Percentages of dry weight (relative density) for plant species in stomach samples of black-tailed prairie dogs collected from Town 11 and Burns Basin in 1973. Trace (tr) is less than 1 percent.

Plant species	Percent dry weight				
	December (8) <sup>a</sup>	May (40)	June-July (14)	August (56)	Annual (118)
Minor Species					
<u>Amaranthus</u> spp.		tr		tr	tr
<u>Aristida</u> spp.		4	1	2	2
<u>Artemisia frigida</u>		tr			tr
<u>Astragalus</u> spp. or <u>Oxytropis</u> spp.		tr	1	1	1
<u>Bromus</u> spp.	tr	tr	2	1	1
<u>Chenopodium</u> spp. or <u>Monolepis nuttalliana</u>		1		tr	tr
<u>Conyza</u> spp. or <u>Ratibida columnifera</u>		tr	1	1	1

<sup>a</sup> sample size in parentheses

Table 1. Continued. Percentages of dry weight (relative density) for plant species in stomach samples of black-tailed prairie dogs collected from Town 11 and Burns Basin in 1973. Trace (tr) is less than 1 percent.

Plant species	Percent dry weight				
	December (8) <sup>a</sup>	May (40)	June-July (14)	August (56)	Annual (118)
<u>Cymopterus acaulis</u>		1			tr
<u>Draba reptans</u>		tr			tr
<u>Dyssodia papposa</u>		tr		1	tr
<u>Euphorbia</u> spp.		tr			tr
<u>Festuca octoflora</u>		tr	1	tr	tr
<u>Gaura coccinea</u>		tr	tr	tr	tr
<u>Hedeoma</u> spp.		tr		tr	tr
<u>Kuhnia eupatorioides</u>				tr	tr
<u>Lepidium densiflorum</u>		tr	tr		tr
<u>Liatris punctata</u>				tr	tr

<sup>a</sup>sample size in parentheses

Table 1. Continued. Percentages of dry weight (relative density) for plant species in stomach samples of black-tailed prairie dogs collected from Town 11 and Burns Basin in 1973. Trace (tr) is less than 1 percent.

Plant species	Percent dry weight				
	December (8) <sup>a</sup>	May (40)	June-July (14)	August (56)	Annual (118)
<u>Munroa squarrosa</u>		tr	tr	3	1
<u>Polygala</u> spp.			tr	1	tr
<u>Psoralea</u> spp.		tr	1	tr	tr
<u>Salsola kali</u>		tr	1	2	1
<u>Schedonnardus paniculatus</u>	1	1	2	3	2
<u>Solanum rostratum</u>			tr	tr	tr
<u>Solanum triflorum</u>		tr	1		tr
<u>Sporobolus cryptandrus</u>		1	6	3	2
<u>Verbena bracteata</u>		tr		tr	tr
<u>Viola nuttallii</u>		1			tr

<sup>a</sup>sample size in parentheses

species of prairie dogs were blue grama, needleleaf sedge (Carex eleocharis), sand dropseed (Sporobolus cryptandrus), and scarlet globemallow (Lerwick 1974). Lerwick (1974) stated that prairie dogs did not consume buffalograss even though it was a dominant grass in the study areas. He found that many annual forbs common in the range were not eaten.

Smith (1958), Koford (1958), Tiletston and Lechleitner (1966), and Kelso (1939) mentioned the importance of pricklypear cactus as a green food item in winter. This was the case in the present study as well. Digging for roots of grasses and forbs in late fall, winter, and early spring was mentioned in each of the studies cited above. I did not find an increase in root-stem material from August to December. Instead, stomachs obtained in winter contained about the same percentage of root-stem material as stomachs collected in August.

Smith (1958) and Koford (1958) found that seed material became important in the summer months. Lerwick (1974) found that seed material on one of his sites became important during the dry period, but on the other site seed material remained unimportant. In this study seed material constituted less than 5 percent of the stomach contents throughout the seasons studied. Smith (1958) and Kelso (1939) mentioned the importance of insects in spring. I found no insect material in the stomachs collected.

When percentage of dry weight in the stomach samples was compared to percentage plant cover for the range survey, it was found that

prairie dogs were selective. Buffalograss was the only major species for which the prairie dogs did not show selectivity (Fig. 24). All other major species were eaten in greater quantities than occurred in the range survey (Figs. 24 and 25). The prairie dogs avoided threeawn, prairie dogweed, and horseweed (Fig. 25). These three species were important in Burns Basin vegetative types.

A paired t-test (Mendenhall 1968) showed that the differences were not significant ( $P > 0.05$ ) in mean relative densities of plant species between stomach and pellet samples collected from Town 11 and Burns Basin (Table 2). Todd and Hansen also found no significant differences between rumen and pellet samples of bighorn sheep in Colorado. It appears that pellet samples could be substituted for stomach samples, and a valid index of the important foods would be obtained. However analysis of pellets evidently underestimated minor species of forbs. Seventeen minor species of forbs (6 percent) were found in the stomach samples of Burns Basin; pellet samples had five minor species (2 percent). On Town 11, 13 minor forb species (4 percent) were found in stomach samples and only 3 species (1 percent) in pellet samples.

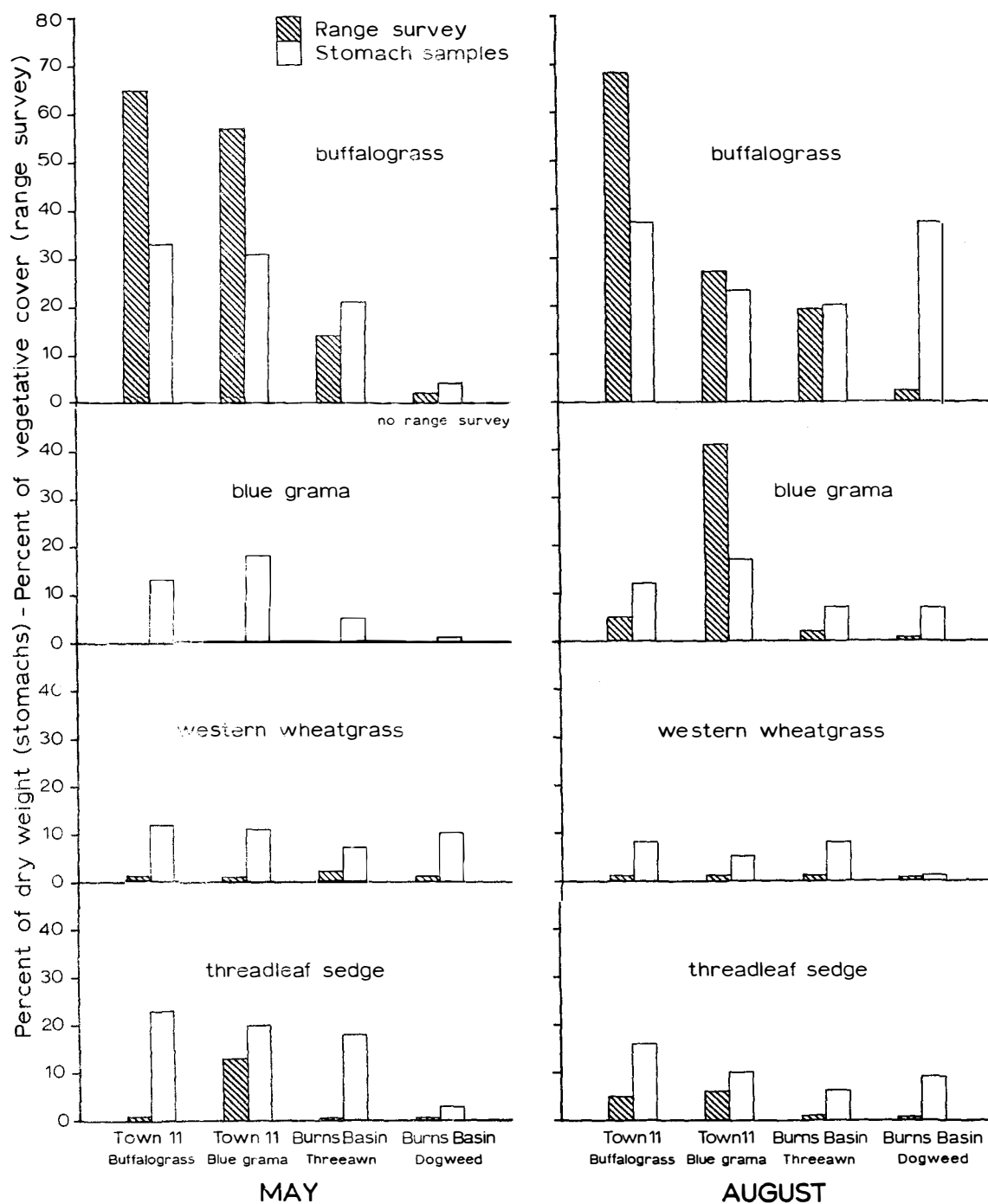


Fig. 24. Comparison of the percentage of dry weight of vegetation in stomachs and percentage of vegetative cover in the range survey in the four vegetative covers for May and August.

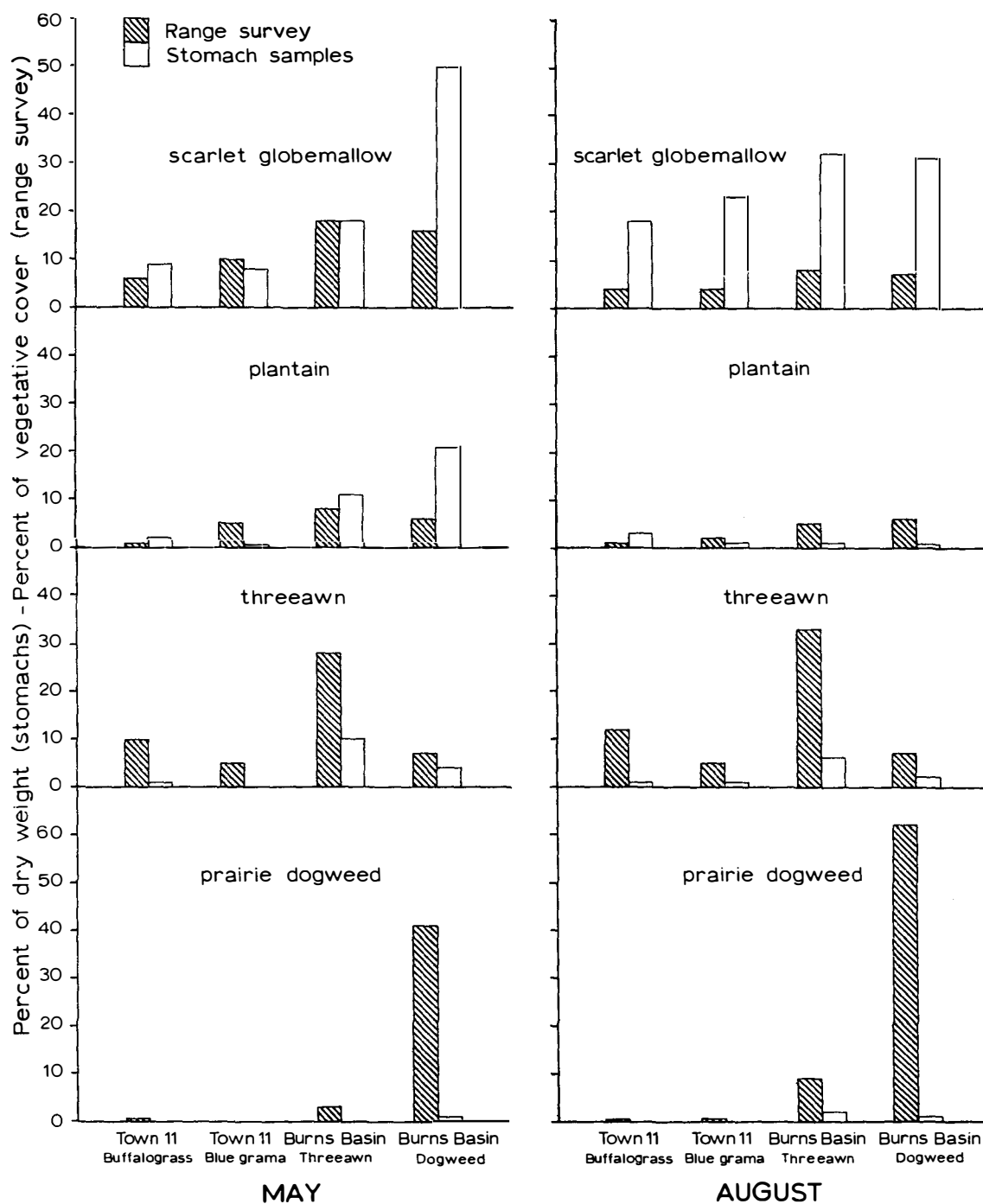


Fig. 25. Comparison of the percentage of dry weight of vegetation in stomachs and percentage of vegetative cover in the range survey in the four vegetative covers for May and August.



Table 2. Percentages of dry weight (relative density) for plant species in stomach and pellet samples collected from Town 11 and Burns Basin for 14-22 May and 1-14 August 1973. Trace (tr) is less than 1 percent.

Plant species	Percent dry weight			
	Town 11		Burns Basin	
	Stomachs (58) <sup>a</sup>	Pellets (16)	Stomachs (38)	Pellets (16)
Total grasses and sedges	80	95	51	83
Total forbs	20	5	48	17
Root-stem and seed material	6	1	10	1
<u>Buchloe dactyloides</u>	31	28	21	28
<u>Carex filifolia</u>	17	19	9	10
<u>Bouteloua gracilis</u>	15	15	5	6
<u>Sphaeralcea coccinea</u>	14	4	33	14
<u>Agropyron smithii</u>	9	19	7	14

<sup>a</sup>sample size in parentheses

Table 2., Continued. Percentages of dry weight (relative density) for plant species in stomach and pellet samples collected from Town 11 and Burns Basin for 14-22 May and 1-14 August 1973. Trace (tr) is less than 1 percent.

Plant species	Percent dry weight			
	Town 11		Burns Basin	
	Stomachs (58) <sup>a</sup>	Pellets (16)	Stomachs (38)	Pellets (16)
<u>Aristida</u> spp.	1	2	6	9
<u>Munroa squarrosa</u>	3	1	tr	4
<u>Schedonnardus paniculatus</u>	2	7	2	11
<u>Sporobolus cryptandrus</u>	2	3	2	1
<u>Plantago</u> spp.	2	tr	8	1

<sup>a</sup>sample size in parentheses

## SUMMARY AND CONCLUSIONS

A key based upon characteristics of epidermal fragments of plants was developed to study food habits of prairie dogs in southwestern South Dakota. Forbs were identified by their trichomes, stomata, subsidiary cells, crystals, cell walls, and cuticle. Identification of the grasses and sedges was based upon long cells, short cells, silica bodies, stomata, macrohairs, microhairs, prickly hairs, and papillae.

In both stomach and pellet samples, the same five plant species were important for spring and summer in all vegetative types of the two study areas, even though the vegetative composition was different on the areas. The five important species were buffalo grass, scarlet globemallow, threadleaf sedge, blue grama, and western wheatgrass. Three species that were important in the range but were avoided in feeding were threeawn, prairie dogweed and horseweed. Insect matter and seed material made up less than 5 percent of the food material. Results of my study did not differ greatly from other studies except that buffalograss comprised the greatest percentage of the stomach contents.

Pricklypear cactus and western wheatgrass increased in importance during the winter, and importance of buffalograss, blue grama, threadleaf sedge, and scarlet globemallow decreased. Root material did not increase in winter.

## LITERATURE CITED

- Al-Rais, A. H., A. Myers, and L. Watson. 1971. The isolation and properties of oxalate crystals from plants. *Ann. Bot.* 35(143): 1213-1218.
- Amhad, K. J. 1964. Cuticular studies in Solanaceae. *Canadian J. Bot.* 42(7): 793-803.
- Baumgartner, L. and A. C. Martin. 1939. Plant histology as an aid in squirrel food-habit studies. *J. Wildl. Manage.* 3(3): 266-268.
- Beetle, A. A. 1970. Recommended plant names. *Agr. Exp. Sta. Res. J.* 31, Univ. of Wyoming, Laramie, 124 pp.
- Bell, W. B. 1920. Death to the rodents. *U. S. Dept. Agric. Yearb.* 1920: 421-438.
- Bergerud, A. T. and L. Russell. 1964. Evaluation of rumen food analysis for Newfoundland caribou. *J. Wildl. Manage.* 28(4): 809-814.
- Cavender, B. R. and R. M. Hansen. 1970. The microscope method used for herbivore diet estimates and botanical analysis of litter and mulch at the Pawnee Site. *U. S. Int. Biol. Grasslands Biome Tech. Rep. No. 18*, 10 pp. *Nat. Res. Ecol. Lab., Ft. Collins.*
- Curtis, J. T. and R. P. McIntosh. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology.* 31(3): 434-455.
- Daubenmire, R. 1959. A canopy-method of vegetational analysis. *N. W. Sci.* 33(1): 43-64.
- Davies, I. 1959. The use of epidermal characteristics for the identification of grasses in the leafy stage. *Brit. Grassl. Soc. J.* 14(1): 7-16.
- Dusi, J. L. 1949. Methods for the determination of food habits by plant microtechniques and histology and their application to cottontail rabbit food habits. *J. Wildl. Manage.* 13(3): 295-298.
- Esau, K. 1965. *Plant Anatomy.* John Wiley & Sons, Inc., New York. 767 pp.

- Fahn, A. 1974. Plant Anatomy. Pergamon Press Ltd, Oxford. 611 pp.
- Foster, A. S. 1949. Practical Plant Anatomy. D. Van. Nostrand Co., Inc., New Jersey. 228 pp.
- Fracker, S. B. and H. A. Brischle. 1944. Measuring the local distribution of ribes. Ecology. 25(3): 283-303.
- Free, J. C., R. M. Hansen, and P. L. Simms. 1970. Estimating dry weights of food plants in feces of herbivores. J. Range Manage. 23(4): 300-302.
- Freese, F. 1960. Testing accuracy. For. Serv. 6(2): 139-145.
- Hansen, R. M., D. G. Peden, and R. W. Rice. 1973. Discerned fragments in feces indicates diet overlap. J. Range Manage. 26(2): 103-105.
- Hercus, B. H. 1960. Plant cuticle as an aid to determine the diet of grazing animals. Proc. Int. Grassl. Congr. 8: 443-447,
- Kelso, L. H. 1939. Food habits of prairie dogs. U. S. Dept. Agric. Circ. 529. 15 pp.
- Koford, C. B. 1958. Prairie dogs, white faces, and blue grama. Wildl. Monogr. No. 3. 78 pp.
- Lerwick, A. C. 1974. The effects of the black-tailed prairie dog on vegetative composition and their diet in relation to cattle. M. S. Thesis. Colo. State Univ., Fort Collins. 106 pp.
- Mendenhall, W. 1968. Introduction to Linear Models and the Design and Analysis of Experiments. Wadsworth Publishing Co., Inc., California. 465 pp.
- Merriam, C. H. 1901. The prairie dog of the great plains. U. S. Dept. Agric. Yearb. 1901: 257-270.
- Metcalf, C. R. 1960. Anatomy of the Monocotyledons: I. Gramineae. Oxford Univ. Press, London. 731 pp.
- Metcalf, C. R. 1971. Anatomy of the Monocotyledons: V. Cyperaceae. Oxford Univ. Press, London. 597 pp.
- Metcalf, C. R. and L. Chalk. 1950. Anatomy of the Dicotyledons. Vols. I and II. Oxford Univ. Press, London. 1500 pp.

- Nelson, E. W. 1918. Annual report of chief of Bureau of Biological Survey. Pages 257-275. in Annual Reports of the Dept. of Agric. for the year ended June 30, 1918.
- Nelson, E. W. 1919. Annual report of chief of Bureau of Biological Survey. Pages 275-298. in Annual Reports of the Dept. of Agric. for the year ended June 30, 1919.
- Norris, J. J. 1943. Botanical analysis of stomach contents as a method of determining forage consumption of range sheep. Ecology. 24(2): 244-251.
- Prat, H. 1936. La systematique des Graminae. Ann. Sci. Nat. Bot. Ser. 10. 18: 165-258.
- Schultz, E. F., Jr. 1955. Rules of thumb for determining expectations of mean squares in analysis of variance. Biometrics. 2(2): 123-135.
- Smith, R. E. 1958. Natural history of the prairie dog in Kansas. Univ. Kan. Mus. Nat. Hist. Mics. Publ. No. 9. 39 pp.
- Solereeder, H. 1908. Systematic Anatomy of the Dicotyledons. Trans. by L. A. Boddle and F. E. Fritsch, revised by D. H. Scott. Claredon Press, Oxford. 1182 pp.
- Sparks, D. R. and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscope technique. J. Range Manage. 21(4): 264-265.
- Spuhler, W., W. R. Lytle, and D. Moe. 1968. Climatological summary: Cottonwood, South Dakota. S. Dak. State U. Agric. Exp. Stn. No. 14. 6 pp.
- Steward, D. R. M. 1967. Analysis of plant epidermis in faeces: A technique for studying the food preferences of grazing herbivores. J. Appl. Ecol. 4: 83-111.
- Storr, G. M. 1961. Microscopic analysis of feces, a technique for ascertaining the diet of herbivorous mammals. Aust. J. Biol. Sci. 14: 157-164.
- Tateoka, T., S. Inoue, and S. Kawano. 1959. Notes on some grasses: IX. Systematic significance of bicellular microhairs of leaf epidermis. Bot. Gaz. 121(2): 80-91.

- Taylor, W. P. 1920. Suggestions for ecologic investigations in vertebrate zoology. *Sci.* 51(1316): 283-287.
- Taylor, W. P. and J. V. G. Loftfield. 1924. Damage to range grasses by the Zuni prairie dog. U. S. Dept. Agric. Bull. 1227. 15 pp.
- Tileston, J. V. and R. R. Lechleitner. 1966. Some comparisons of the black-tailed and white-tailed prairie dogs in north-central Colorado. *Am. Midl. Nat.* 75(2): 292-316.
- Todd, J. W. and R. M. Hansen. 1973. Plant fragments in the feces of bighorns as indicators of food habits. *J. Wildl. Manage.* 37(3): 363-365.
- Ueckert, D. N. and R. M. Hansen. 1971. Dietary overlap of grasshoppers on sandhill rangehand in northeastern Colorado. *Oecologia (Berl.)*. 8(3): 276-295.
- Uphof, J. C. and K. Hummel. 1962. Plant Hairs in K. Linsbauer, ed. *Hanbuch der Pflanzenanatomie*. Vol 4, Part 5. Gehr. Borntraeger, Berlin.
- U. S. Dept. Interior. 1963. Inventory of areas occupied by prairie dogs in 1961. Circular letter, Branch of Predator and Rodent Control. U. S. Fish and Wildlife.

## APPENDIX



Appendix A. List of dicotyledons on study areas (Beetle 1970) and species descriptions to Section I of key.

---



---

<u>Amaranthus albus</u> L.	tumble pigweed
<u>Amaranthus graecizans</u> L.	prostrate pigweed
<u>Artemisia frigida</u> Willd.	fringed sagewort
<u>Asclepias pumila</u> (A. Gray) Vail	plains milkweed
<u>Aster ericoides</u> L.	heath aster
<u>Astragalus agrestis</u> Dougl.	field milkvetch
<u>Chenopodium incanum</u> (S. Wats.) Heller	goosefoot
<u>Chenopodium leptophyllum</u> Nutt.	narrowleaf goosefoot
<u>Chrysopsis villosa</u> Nutt.	narrowleaf goldenaster
<u>Conyza canadensis</u> (L.) Cron.	Canada horseweed
<u>Conyza ramosissima</u> Cron.	horseweed
<u>Cryptantha minima</u> Rydb.	cryptantha
<u>Cymopterus acaulis</u> (Pursh) Raf.	stemless springparsley
<u>Draba reptans</u> (Lam.) Fern.	draba
<u>Dyssodia papposa</u> (Vent.) Hitchc.	prairie dogweed
<u>Euphorbia fendleri</u> Torrey & Gray	fendler spurge
<u>Euphorbia glyptosperma</u> Engelm.	ridgeseed spurge
<u>Euphorbia marginata</u> Pursh	snow-on-the-mountain spurge
<u>Gaura coccinea</u> (Nutt.) Pursh	scarlet gaura
<u>Hedeoma hispida</u> Pursh	rough falsepennyroyal
<u>Hedeoma pulegioides</u> (L.) Pens.	American falsepennyroyal
<u>Helianthus</u> spp.	sunflower

<u>Kuhnia eupatorioides</u> L.	false prairieboneset
<u>Lappula</u> spp.	stickweed
<u>Lepidium densiflorum</u> Schrader	prairie pepperweed
<u>Liatris punctata</u> Hook.	dotted gayfeather
<u>Linum rigidum</u> Pursh	stiffstem flax
<u>Mirabilis linearis</u> (Pursh) Heimerl.	narrowleaf fourclock
<u>Monolepis nuttalliana</u> (Schult.) Greene	nuttall monolepis
<u>Oenothera albicaulis</u> Pursh	prairie eveningprimrose
<u>Opuntia polyacantha</u> Haw.	plains pricklypear cactus
<u>Oxytropis</u> spp.	loco
<u>Plantago aristata</u> Michx.	bracted plantain
<u>Plantago patagonica</u> Jacq.	woolly plantain
<u>Plantago spinulosa</u> Dcne.	spiny plantain
<u>Polygala alba</u> Nutt.	white polygala
<u>Polygala verticillata</u> L.	polygala
<u>Polygonum aviculare</u> L.	prostrate knotweed
<u>Psoralea argophylla</u> Pursh	silverleaf scurfpea
<u>Psoralea cuspidata</u> Pursh	tallbread scurfpea
<u>Psoralea tenuiflora</u> Pursh	slimflower scurfpea
<u>Ratibida columnifera</u> (Nutt.) Woot. & Standl.	prairie coneflower
<u>Salsola kali</u> L.	common russianthistle
<u>Salvia reflexa</u> Hornem.	lanceleaf sage
<u>Solanum rostratum</u> Dunal	buffalobur nightshade
<u>Solanum triflorum</u> Nutt.	cutleaf nightshade

<u>Sphaeralcea coccinea</u> (Pursh) Rydb.	scarlet globemallow
<u>Taraxacum officinale</u> Weber	common dandelion
<u>Verbena bracteata</u> Lab. & Rodr.	bigbract verbena
<u>Viola nuttallii</u> Pursh	yellow prairie violet
<u>Zygadenus paniculatus</u>	deathcamas

#### Descriptions of Dicotyledon Species

Amaranthus albus L. Leaf: margin undulating; infrequent uniseriate hairs with oval to oblong cells tapering to rounded tip; anomocytic to anisocytic; irregular cells with wavy to semi-wavy anticlinal walls; druses. Stem: infrequent uniseriate hairs with round to oblong cells tapering to rounded tip; rectangular cells oriented horizontally; oblong cluster crystals (druses).

Amaranthus graecizans L. Leaf: margin undulating; infrequent uniseriate hairs with oval to oblong cells tapering to rounded tip; anomocytic to anisocytic; irregular cells with wavy to semi-wavy anticlinal walls; druses. Stem: infrequent uniseriate hairs with round to oblong cells tapering to rounded tip; rectangular cells oriented horizontally; oblong cluster crystals (druses).

Artemisia frigida Willd. Leaf: strand unicellular hairs; rosette shapes present.

Asclepias pumila (A. Gray) Vail Leaf: papillose, uniseriate hairs with oblong to rounded cells, terminal cell often enlarged or club-shaped; paracytic; polygonal cells with straight anticlinal walls; druses. Stem: papillose, uniseriate hairs with oblong to rounded

cells, terminal cell often enlarged or club-shaped; modified anomocytic; distorted rectangular cells oriented horizontally; druses.

Aster ericoides L. Leaf: smooth uniseriate hairs with rectangular to square cells tapering to a pointed tip; base whorled; foot composed of single cell; uniseriate hairs with modified terminal cell, elongated, narrowed, sharply pointed; anisocytic, subsidiary cells often different in shape from other epidermal cells; irregular cells with semi-wavy anticlinal walls; cuticle often ridged. Stem: smooth uniseriate hairs with rectangular to square cells tapering to a pointed tip; base whorled; foot composed of single cell; anisocytic with all 3 cells of different shape than surrounding epidermal cells; straight to semi-wavy anticlinal walls; cells generally not oriented horizontally.

Astragalus agrestis Dougl. Leaf: stout cylindrical to dentiform, papillose, unicellular hairs; raised, circular base; anomocytic; polygonal to oval cells with straight anticlinal walls. Stem: stout cylindrical to dentiform, papillose, unicellular hairs; raised, circular base; paracytic; rectangular cells oriented horizontally.

Chenopodium incanum (S. Wats.) Heller Leaf: vesicular hairs with uniseriate stalks; circular base; anomocytic; irregular to oval cells with straight to semi-wavy anticlinal walls; druses.

Chenopodium leptophyllum Nutt. Leaf: vesicular hairs with uniseriate stalks; circular base; anomocytic; irregular to oval cells with straight to semi-wavy anticlinal walls; druses.

Chrysopsis villosa Nutt. Leaf: uniseriate hairs with rectangular to square cells tapering to a pointed tip; modified whorled base; foot composed of single cell; uniseriate hairs with modified terminal cell, elongated, narrowed and sharply pointed; anisocytic; often epidermal cells somewhat elongated between stomata, semi-wavy anticlinal walls with prominent pitting. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip; modified whorled base; foot composed of single cell; anisocytic; irregular cells oriented somewhat horizontally.

Conyza canadensis (L.) Cron. Leaf: uniseriate hairs with rectangular to square cells tapering to a pointed tip; whorled base; foot composed of several cells often impregnated; anisocytic; irregular cells with semi-wavy to straight anticlinal walls; series of oval structures in mesophyll. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip; whorled base; foot composed of several cells often impregnated; anisocytic to paracytic; rectangular to distorted cells oriented horizontally.

Conyza ramosissima Cron. Leaf: uniseriate hairs with rectangular to square cells tapering to a pointed tip; whorled base; foot composed of several cells often impregnated; anisocytic; irregular cells with semi-wavy to straight anticlinal walls; series of oval structures in mesophyll. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip; whorled base; foot composed of several cells often impregnated; anisocytic to paracytic; rectangular to distorted shaped cells oriented horizontally.

Cryptantha minima Rydb. Leaf: dentiform unicellular hairs; whorled base; anomocytic; irregular shaped cells with wavy anticlinal walls.

Stem: dentiform, unicellular hairs; whorled base; rectangular shaped cells oriented horizontally.

Cymopterus acaulis (Pursh) Raf. Leaf: conical papillae; muricate surface; anisocytic; irregular cells with wavy anticlinal walls; slightly ridged cuticle. Stem: conical papillae; anisocytic; rectangular cells oriented horizontally.

Draba reptans (Lam.) Fern. Leaf: forked or branched, papillose, unicellular hairs; circular to whorled base; dentiform, thick walled, unicellular hairs occasionally present; circular base; anisocytic to anomocytic; irregular cells with wavy to semi-wavy anticlinal walls. Stem: forked or branched, papillose, unicellular hairs; circular to whorled base; irregular cells oriented somewhat horizontally.

Dyssodia papposa (Vent.) Hitchc. Leaf: uniseriate hairs with oblong to rounded cells tapering to a rounded tip, terminal cell similar shape as proximal cell only with narrower width; semi-anisocytic; oblong to oval cells with semi-wavy to straight anticlinal walls, prominent pitting; surface glands. Stem: uniseriate hairs with oblong to rounded cells tapering to a rounded tip, terminal cell similar shape as proximal cell only with narrower width; anisocytic; irregular cells oriented horizontally.

Euphorbia fendleri Torrey & Gray Leaf: glabrous; smooth to slightly undulating margin; anomocytic; irregular to polygonal cells with wavy to straight anticlinal walls depending on adaxial or abaxial surface.

Stem: glabrous; rectangular cells oriented horizontally.

Euphorbia glyptosperma Engelm. Leaf: glabrous; smooth to undulating margin; anomocytic; irregular to polygonal cells with wavy to straight anticlinal walls depending on adaxial or abaxial surface.

Stem: glabrous; rectangular cells oriented horizontally.

Euphorbia marginata Pursh Leaf: generally glabrous; smooth to undulating margin; infrequent strand, unicellular hairs; anomocytic; irregular to polygonal cells with wavy to straight anticlinal walls depending on adaxial or abaxial surface. Stem: generally glabrous; infrequent strand, unicellular hairs; rectangular cells oriented horizontally.

Gaura coccinea (Nutt.) Pursh Leaf: medium to short papillose, dentiform unicellular hairs, if larger hairs present accompanied by shorter hairs; circular base; anomocytic; irregular cells with wavy to semi-wavy anticlinal walls. Stem: papillose, dentiform unicellular hairs; circular base; rectangular, narrowed cells.

Hedeoma hispida Pursh Leaf: papillose, uniseriate hairs with rectangular to square cells tapering to a pointed tip; circular base; small bristles with pointed and blunt ends; anomocytic; irregular cells with wavy anticlinal walls.

Hedeoma pulegioides (L.) Pens. Leaf: papillose, uniseriate hairs with rectangular to square cells tapering to a pointed tip; circular base; small bristles with pointed to blunt ends; anomocytic; irregular cells with wavy anticlinal walls.

Helianthus spp. Leaf: uniseriate hairs with rectangular to square

cells tapering to a pointed tip, often papillose; circular or whorled base; large bristles with pointed ends; anomocytic; irregular cells with wavy anticlinal walls. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip, often papillose; raised, circular, large base; anomocytic; oval cells with semi-wavy anticlinal walls.

Kuhnia eupatorioides L. Leaf: uniseriate hairs with oblong to rounded cells tapering to a long oblong terminal cell, proximal portion of hair moniliform; smaller, less frequent, uniseriate hairs with terminal cell bulbous; anomocytic; polygonal cells with straight anticlinal walls. Stem: uniseriate hairs with oblong to rounded cells tapering to a long oblong terminal cell, proximal portion of hair moniliform; raised, circular base; elongated rectangular cells oriented horizontally.

Lappula spp. Leaf: dentiform unicellular hairs; circular to whorled base; anomocytic; irregular shaped cells with wavy to semi-wavy anticlinal walls, one surface oriented horizontally. Stem: dentiform unicellular hairs; circular base; rectangular cells oriented horizontally.

Lepidium densiflorum Schrader Leaf: large conical to oblong, papillose, papillae; diacytic; stomata generally grouped with larger cells between groups; irregular shaped cells with semi-wavy anticlinal walls. Stem: large conical to oblong, papillose, papillae; diacytic; rectangular cells oriented horizontally.



Liatris punctata Hook. Leaf: cuticle papillae; anomocytic anisocytic; irregular cells with semi-wavy anticlinal walls; surface glands.

Stem: similar to leaf.

Linum rigidum Pursh Leaf: multicellular, glandular hairs; cuticle papillae; paracytic; polygonal cells with straight anticlinal walls.

Stem: oblong papillae infrequent; cuticle papillae; paracytic; polygonal, often rectangular, cells oriented horizontally.

Mirabilis linearis (Pursh) Heimerl. Leaf: uniseriate hairs with oblong to rounded cells, terminal cell bulbous; modified anisocytic with 1 cell smaller and 2 to 3 larger subsidiary cells; polygonal cells with straight anticlinal walls; raphides; black tinge to cuticle. Stem: uniseriate hairs with oblong to rounded cells, terminal cell bulbous; anisocytic; rectangular cells oriented horizontally; black tinge to cuticle.

Monolepis nuttalliana (Schult.) Greene Leaf: vesicular hairs with uniseriate stalks; small circular base; anomocytic; oval cells with straight to semi-wavy anticlinal walls; druses.

Oenothera albicaulis Pursh Leaf: dentiform, unicellular hairs; slender cylindrical, unicellular hairs; circular base; anomocytic; oval cells with straight to semi-wavy anticlinal walls; raphides.

Stem: cylindrical, unicellular hairs; circular base.

Opuntia polvacantha Haw. Leaf: uniseriate hairs with oblong to rounded cells tapering to blunt or rounded tip; hairs very long with oblong cells often impregnated, mesh pattern on cell walls of hair; very small cuticle papillae; paracytic to acinocytic; polygonal to

oval cells with straight to semi-wavy anticlinal walls; druses.

Oxytropis spp. Leaf: T-shaped unicellular, papillose hairs; raised circular base; anisocytic; polygonal to oval cells with straight anticlinal walls, often with prominent pitting. Stem: T-shaped, papillose, unicellular hairs; raised, circular base; paracytic, or stomata surrounded by single subsidiary cell; irregular to rectangular cells oriented horizontally.

Plantago aristata Michx. Leaf: uniseriate hairs with rectangular to square cells tapering to a pointed tip, hairs composed of thin, elongated cells raised, circular base; glandular hairs with two celled globose distal end and 1-2 celled stalk; anisocytic to diacytic; irregular cells with wavy to semi-wavy anticlinal walls; cells oriented horizontally. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip, hairs composed of thin, elongated cells; raised, circular base; diacytic; narrowed rectangular cells oriented horizontally.

Plantago patagonica Jacq. Leaf: uniseriate hairs with rectangular to square cells tapering to a pointed tip; hairs composed of thin, elongated cells; raised, circular base; glandular hairs with two cells globose distal end and 1-2 celled stalk; anisocytic to diacytic; irregular cells with wavy to semi-wavy anticlinal walls; cells oriented horizontally. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip, hairs composed of thin, elongated cells; raised, circular base; diacytic; narrowed rectangular shaped cells oriented horizontally.

Plantago spinulosa Dcne. Leaf: uniseriate hairs with rectangular to square cells tapering to a pointed tip; hairs composed of thin, elongated cells; raised, circular base; glandular hairs with two celled globose distal end and 1-2 celled stalk; anisocytic to diacytic; irregular cells with wavy to semi-wavy anticlinal walls; cells oriented horizontally. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip, hairs composed of thin, elongated cells; raised, circular base; diacytic; narrowed rectangular cells oriented horizontally.

Polygala alba Nutt. Leaf: small, unicellular, cylindrical hairs, infrequent; bullate surface; anomocytic; irregular cells with wavy to straight anticlinal walls depending on adaxial or abaxial surface. Stem: small, unicellular, cylindrical hairs infrequent; paracytic; occasionally anisocytic; narrow rectangular cells oriented horizontally.

Polygala verticillata L. Leaf: small, unicellular, cylindrical hairs, infrequent; bullate surface; anomocytic; irregular cells with wavy to straight anticlinal walls depending on adaxial or abaxial surface. Stem: small, unicellular, cylindrical hairs, infrequent; paracytic, occasionally anisocytic; narrow rectangular cells oriented horizontally.

Polygonum aviculare L. Leaf: glabrous; bullate surface; anisocytic to paracytic; polygonal cells with straight anticlinal walls; ridged cuticle; druses. Stem: glabrous; paracytic with some variation; polygonal cells; ridged cuticle.

Psoralea argophylla Pursh Leaf: T-shaped, unicellular, papillose hairs; raised, circular base; anisocytic to anomocytic; oval to

polygonal cells with semi-wavy to straight anticlinal walls, pitting present. Stem: T-shaped, unicellular, papillose hairs; raised, circular base; paracytic; irregular to rectangular cells.

Psoralea cuspidata Pursh Leaf: dentiform, unicellular hairs; raised, circular base; small glandular hairs; paracytic; polygonal cells with straight to semi-wavy anticlinal walls; surface glands. Stem: dentiform, unicellular hairs; raised, circular base; paracytic; irregular cells, somewhat rectangular, with straight anticlinal walls.

Psoralea tenuiflora Pursh Leaf: dentiform, unicellular hairs; raised, circular base; small glandular hairs; paracytic; polygonal cells with straight to semi-wavy anticlinal walls; surface glands. Stem: dentiform, unicellular hairs; raised, circular base; paracytic; irregular cells, somewhat rectangular, with straight anticlinal walls.

Ratibida columnifera (Nutt.) Woot. & Standl. Leaf: uniseriate hairs with rectangular to square cells tapering to a pointed tip, often papillose; whorled base; anomocytic distorted oval cells with semi-wavy anticlinal walls. Stem: uniseriate hairs with rectangular to square cells tapering to a pointed tip, often papillose; whorled base; anomocytic; distorted cells, somewhat rectangular, with straight anticlinal walls.

Salsola kali L. Leaf: conical to oblong papillae; paracytic; hexagonal cells with straight anticlinal walls; druses. Stem: conical to oblong papillae; paracytic; rectangular, elongated, cells with straight anticlinal walls oriented horizontally.

Salvia reflexa Hornem. Leaf: uniseriate hairs with oblong to round cells tapering to blunt or rounded tip; circular base; bristles with pointed tip; glandular hairs with 4-celled terminal bulb; anisocytic; irregular cells with wavy anticlinal walls; small, solitary, prismatic crystals. Stem: uniseriate hairs with oblong to round cells tapering to blunt or rounded tip; circular base; paracytic; distorted polygonal cells with straight anticlinal walls.

Solanum rostratum Dunal Leaf: tufted to candelabra hairs; multicellular, glandular hairs; anomocytic; irregular cells with wavy to semi-wavy anticlinal walls; druses. Stem: tufted or candelabra hairs; rosette base; multicellular, glandular hairs.

Solanum triflorum Nutt. Leaf: papillose, uniseriate hairs with oblong to rounded cells tapering to blunt or rounded tip, terminal cell narrower than proximal cells; multicellular glandular hairs with unicellular stalk and multicellular globose distal end; anomocytic to anisocytic; irregular cells with wavy to semi-wavy anticlinal walls. Stem: papillose, uniseriate hairs with oblong to rounded shaped cells tapering to blunt or rounded tip, terminal cell narrower than proximal cells; large circular base; paracytic; elongated, rectangular cells oriented horizontally.

Sphaeralcea coccinea (Pursh) Rydb. Leaf: stellate hairs; rosette base; anisocytic; irregular cells with semi-wavy anticlinal walls; druses. Stem: stellate hairs; rosette base; druses.

Taraxacum officinale Weber Leaf: glabrous; smooth margin; anisocytic to anomocytic; irregular cells with wavy anticlinal walls.

Verbena bracteata Lab. & Rodr. Leaf: dentiform, unicellular hairs; whorled base; anomocytic; irregular to oval cells with wavy to straight anticlinal walls depending on abaxial or adaxial surface, pitting on one surface. Stem: dentiform, unicellular hairs; whorled base; modified anomocytic to anisocytic; rectangular cells oriented horizontally.

Viola nuttallii Pursh Leaf: conical to oblong, papillose, papillae; anisocytic; irregular cells with semi-wavy anticlinal walls; druses. Stem: conical to oblong, papillose, papillae; rectangular cells oriented horizontally.

Appendix B. List of monocotyledons on study areas (Beetle 1970)  
and species descriptions to Section II of key.

---



---

<u>Agropyron smithii</u> Rydb.	western wheatgrass
<u>Aristida fendleriana</u> Steudal	fendler threeawn
<u>Aristida longiseta</u> Steudal	red threeawn
<u>Bouteloua gracilis</u> (H.B.K.) Lab.	blue grama
<u>Bromus japonicus</u> Thunb.	japanese brome
<u>Bromus tectorum</u> L.	cheatgrass brome
<u>Buchloe dactyloides</u> (Nutt.) Engelm.	buffalograss
<u>Carex filifolia</u> Nutt.	threadleaf sedge
<u>Festuca octoflora</u> Walt.	sixweeks fescue
<u>Munroa squarrosa</u> (Nutt.) Torr.	false buffalograss
<u>Schedonnardus paniculatus</u> (Nutt.) Trel.	tumblegrass
<u>Sporobolus cryptandrus</u> (Torr.) Gray	sand dropseed

#### Descriptions of Monocotyledon Species

Agropyron smithii Rydb. Type I. Intercostal region: stomata with low-dome-shaped subsidiary cells; long cells with thick, sinuous walls; short cells of two types, (1) in pairs, small circular cell fitting into tall and narrow cell, silica body thin and curved contained in circular cell, and (2) in singles, tall and narrow cell; small prickles with rounded bases; small, circular, cuticle papillae on long cells; microhairs and macrohairs not found. Costal region: long cells sinuous; short cells of two types, (1) in singles, circular

pitted cells, and (2) in pairs, circular, pitted cell and tall and narrow cell with thin, curved silica body; prickles with rounded bases; macrohairs not found. Type II. Long cells with very sinuous thick walls; short cells in pairs with small, circular cell fitting into tall and narrow cell, circular cell containing thin, curved silica body.

Aristida fendleriana Steudal Type I. Intercostal region: stomata with triangular subsidiary cells; long cells thin walled and sinuous; short cells of three types, (1) in pairs, one cell dumb-bell-shaped with close fitting silica body of similar shape, other cell square, (2) in pairs, one cell square and other cell circular and fitting into square cell, silica body close fitting and circular, and (3) in singles, tall and narrow cell; microhairs with long, narrow proximal cell and shorter, but narrowed, distal cell tapering to the apex. Costal region: long cells sinuous; short cells in singles, dumb-bell-shaped cell with similar shaped silica body; small macrohairs present. Type II. Intercostal region: stomata with triangular subsidiary cells; long cells extremely sinuous, giving appearance of thickness; large area with short cells in pairs, one cell oval with close fitting silica body of similar shape, other cell tall, oval cell, short cells also in singles with oval cell containing similar shaped silica body; short macrohairs with rounded bases. Costal region: long cells sinuous; short cells in singles, dumb-bell-shaped cell with similar shaped silica body; bristles present.



Aristida longiseta Steudal Type I. Intercostal region: stomata with triangular subsidiary cells; long cells thin walled and sinuous; short cells of three types, (1) in pairs, one cell dumb-bell-shaped with close fitting silica body of similar shape, other cell square, (2) in pairs, one cell square and other cell circular and fitting into square cell, silica body close fitting and circular, and (3) in singles, tall and narrow cell; microhairs with long, narrow proximal cell and shorter, but narrowed, distal cell tapering to the apex. Costal region: long cells sinuous; short cells in singles, dumb-bell-shaped cell with similar shaped silica body; small macrohairs present. Type II. Intercostal region: stomata with triangular subsidiary cells; long cells extremely sinuous, giving appearance of thickness; large area with short cells in pairs, one cell oval with close fitting silica body of similar shape, other cell tall, oval cell; short cells also in singles with oval cell containing similar shaped silica body; short macrohairs with rounded bases. Costal region: long cells sinuous; short cells in singles, dumb-bell-shaped cell with similar shaped silica body; bristles present.

Bouteloua gracilis (H.B.K.) Lab. Type I. Intercostal region: stomata with triangular subsidiary cells; long cells sinuous, some with papillae present; short cells in pairs generally both tall and narrow cells with one containing similar shaped silica body, occasionally square cell with similar shaped silica body accompanied by a tall and narrow cell; microhairs present with proximal cell tapering and distal cell elongated hemispherical shaped; small macrohairs present.

Costal region: long cells sinuous; short cells in singles, saddle-shaped cell with silica body similar shape; short cells rarely in twos with one cell saddle-shaped containing silica body of similar shape; prickles present; macrohairs present. Type II. Intercostal region: stomata with triangular subsidiary cells; long cells very sinuous with dark cast; large area with short cells in pairs, both cells tall and narrow with one containing similar shaped silica body; small macrohairs; microhairs present with proximal cell tapering and distal cell elongated hemispherical-shaped. Costal region: long cells very sinuous; short cells generally in singles, saddle-shaped with similar shaped silica body, rarely in pairs with one cell saddle-shaped containing silica body of similar shape; prickles and macrohairs present.

Bromus japonicus Thunb. Type I. Intercostal region: stomata with parallel-sided subsidiary cells; long cells with sinuous walls, occasionally with cuticular papillae; short cells of three types, (1) singular, circular, pitted cells, (2) pairs with one small, rounded cell with thin, curved silica body, other cell square to rectangular, and (3) in singles, tall and narrow cell; macrohairs present; microhairs and prickles not found. Costal region: long cells thin walled, slightly sinuous or straight walled; short cells in singles or pairs, cells elongated horizontally with rounded ends with either smooth or somewhat sinuous sides, silica bodies close fitting and similar shape as cell; macrohairs present; prickles not found. Type II. Intercostal region: stomata with parallel-sided subsidiary cells; long cells with thin straight walls; short cells

very infrequent, when present solitary, tall and narrow cell; macrohairs present; microhairs and prickles not found. Costal region: long cells with thin, straight walls; short cells in singles or pairs, horizontally elongated with rounded ends and sides either smooth or somewhat sinuous, silica body close fitting and similar shape as cell; macrohairs present; prickles not found.

Bromus tectorum L. Type I. Intercostal region: stomata with parallel-sided subsidiary cells; long cells with sinuous walls, occasionally with cuticular papillae; short cells of three types, (1) singular, circular, pitted cells, (2) pairs with one small rounded cell with a thin, curved silica body, other cell square to rectangular, and (3) in singles, tall and narrow cell; macrohairs present; microhairs and prickles not found. Costal region: long cells thin walled, slightly sinuous or straight walled; short cells in singles or pairs, cells elongated horizontally with rounded ends either smooth or somewhat sinuous sides, silica bodies close fitting and similar shaped as cell; macrohairs present; prickles not found. Type II. Intercostal region: stomata with parallel-sided subsidiary cells; long cells with thin straight walls; short cells very infrequent, when present, solitary, tall and narrow cell; macrohairs present; microhairs and prickles not found. Costal region: long cells with thin, straight walls; short cells in singles or pairs, horizontally elongated with rounded ends and sides either smooth or somewhat sinuous, silica body close fitting and similar shaped as cell; macrohairs present; prickles not found.

Buchloe dactyloides (Nutt.) Engelm. Type I. Intercostal region:

stomata with triangular subsidiary cells; long cells sinuous, circular papillae often present; short cells of three types, (1) in singles, tall and narrow cell without silica body, (2) in pairs, both cells tall, narrow to square without silica body, and (3) in pairs, one cell smaller and square containing C- to J-shaped silica body, other cell tall and narrow; microhairs present, basal cell tapering and more than four times the length of the distal cell, distal cell hemispherical and not elongated; macrohairs present with base in cushion of irregular shaped epidermal cells. Costal region: long cells sinuous; short cells in singles, saddle-shaped with similar shaped silica body, rarely in pairs, if present other cell rectangular; prickles present. Type II. Intercostal region: stomata with triangular subsidiary cells; long cells very sinuous with dark cast; short cells of three types, (1) in singles, tall and narrow cell without silica body, (2) in pairs, both cells tall, narrow to square without silica body, (3) in pairs, one cell smaller and square, containing C- to J-shaped silica body, other cell tall and narrow; large section with very sinuous long cells and short cells mostly in pairs with one cell saddle-shaped with similar shaped silica body and other cell crescent-shaped to rectangular; microhairs present; macrohairs not seen in this region. Costal region: long cells very sinuous; short cells in singles, saddle-shaped with similar shaped silica body, rarely in pairs, with second cell rectangular.

Carex filifolia Nutt. Stomata with low-dome-shaped to triangular subsidiary cells; short cells absent; long cells very sinuous; papillae present; prickles present.

Festuca octoflora Walt. Type I. Intercostal region: stomata with parallel-sided subsidiary cells; long cells with sinuous walls; short cells in pairs with one smaller circular cell fitting into tall and narrow cell, silica body thin and curved inside circular cell; small prickles with rounded bases infrequent; microhairs and macrohairs not found. Costal region: long cells narrow and sinuous; short cells in singles or pairs, horizontally elongated cells with rounded ends, silica body close fitting with similar shape, other cell square. Type II. Long cells narrow and sinuous; short cells in pairs with one small, circular cell fitting into tall and narrow cell, silica body thin curved inside circular cell.

Munroa squarrosa (Nutt.) Torr. Type I. Intercostal region: stomata with triangular subsidiary cells; long cells sinuous, circular papillae present; short cells of three types, (1) in pairs, with one cell square to cross-shaped with similar shaped silica body, other cell square to tall and narrow, (2) in pairs, with one cell oval to square with silica body C- to J-shaped, other cell crescent-shaped, (3) in singles, cell square to tall and narrow with no silica body; microhairs present with short proximal and distal cells of similar lengths; prickles present. Costal region: long cells sinuous; short cells generally in pairs, from saddle- to cross-shaped containing similar shaped silica body, other cell square to crescent-shaped, less frequently short cells in singles with cross-shaped silica body in similar shaped cell; prickles present. Type II. Intercostal region: stomata with triangular subsidiary cells; long cells very sinuous; large area with short cells in pairs, from

saddle to oval to cross-shaped cells with similar shaped silica body other cell square to crescent shaped. Costal region: long cells very sinuous; short cells in singles and pairs, cross-shaped cells with similar shaped silica body, other cell if present crescent to rectangular shaped; prickles present.

Schedonnardus paniculatus (Nutt.) Trel. Type I. Intercostal region: stomata with triangular shaped subsidiary cells; long cells sinuous, papillae abundant; short cells infrequent, square to tall and narrow; macrohairs present; microhairs present, basal cell tapering, 2 to 3 times longer than distal cell, distal cell tapering with apex rounded. Costal region: long cells sinuous; short cells in singles with saddle to angled shaped cells and silica body angular to square shaped; prickles present. Type II. Long cells very sinuous; short cells in singles, saddle-shaped cells with square to angled silica body, few cross-shaped with angled silica body; microhairs present; prickles and macrohairs present.

Sporobolus cryptandrus (Torr.) Gray Type I. Intercostal region: stomata with triangular shaped subsidiary cells; long cells generally with sinuous walls, often with dark casts; short cells of two types, (1) in pairs, with one cell square to tall and narrow containing silica body C to J shaped, other cell larger tall and narrow, and (2) in single, tall and narrow cell with no silica body; microhairs abundant, basal cell about twice the length of distal cell, distal cell tapering to extended, rounded tip. Costal region: long cells sinuous; short cells generally in pairs but also singles, cells saddle to cross-shaped with similar shaped silica bodies, other cell crescent to square

shaped; prickles present. Type II. Intercostal region: stomata with triangular subsidiary cells; long cells sinuous, often with dark cast; large area with short cells in pairs with one cell saddle-shaped and silica body of similar shape, other cell rectangular to crescent-shaped; microhairs present. Costal region: long cells sinuous; short cells generally in pairs with one cell saddle-shaped with close fitting silica body of similar shape, other cell square to crescent-shaped.

## Appendix C. Supplement to Section I of key.

Trichomes

## Hairs absent or infrequent: Subsection A

- |                                |                               |
|--------------------------------|-------------------------------|
| 1. <u>Amaranthus albus</u>     | 2. <u>A. graecizans</u>       |
| 3. <u>Euphorbia fendleri</u>   | 4. <u>E. glyptosperma</u>     |
| 5. <u>E. marginata</u>         | 6. <u>Polygala alba</u>       |
| 7. <u>P. verticillata</u>      | 8. <u>Polygonum aviculare</u> |
| 9. <u>Taraxacum officinale</u> |                               |

## Papillae: Subsection A

- |                               |                                |
|-------------------------------|--------------------------------|
| 1. <u>Cymopterus acaulis</u>  | 2. <u>Lepidium densiflorum</u> |
| 3. <u>Liatris punctata</u>    | 4. <u>Linum rigidum</u>        |
| 5. <u>Opuntia polyacantha</u> | 6. <u>Salsola kali</u>         |
| 7. <u>Viola nuttallii</u>     |                                |

## Unicellular branched or forked hairs: Subsection B

- |                               |                          |
|-------------------------------|--------------------------|
| 1. <u>Draba reptans</u>       | 2. <u>Oxytropis</u> spp. |
| 3. <u>Psoralea argophylla</u> |                          |

## Unicellular cylindrical hairs: Subsection B

- |                               |                                |
|-------------------------------|--------------------------------|
| 1. <u>Astragalus agrestis</u> | 2. <u>Oenothera albicaulis</u> |
| 3. <u>Polygala alba</u>       | 4. <u>P. verticillata</u>      |

## Unicellular bristles: Subsection B

- |                           |                          |
|---------------------------|--------------------------|
| 1. <u>Hedeoma hispida</u> | 2. <u>H. pulegioides</u> |
| 3. <u>Helianthus</u> spp. | 4. <u>Salvia reflexa</u> |



## Unicellular strand hairs: Subsection B

- |                             |                               |
|-----------------------------|-------------------------------|
| 1. <u>Artemisia frigida</u> | 2. <u>Euphorbia marginata</u> |
|-----------------------------|-------------------------------|

## Unicellular dentiform hairs: Subsection B

- |                                |                              |
|--------------------------------|------------------------------|
| 1. <u>Astragalus agrestis</u>  | 2. <u>Cryptantha minima</u>  |
| 3. <u>Gaura coccinea</u>       | 4. <u>Lappula</u> spp.       |
| 5. <u>Oenothera albicaulis</u> | 6. <u>Psoralea cuspidata</u> |
| 7. <u>P. tenuiflora</u>        | 8. <u>Verbena bracteata</u>  |

## Stellate, candelabra, or tufted hairs: Subsection C

- |                             |                                |
|-----------------------------|--------------------------------|
| 1. <u>Solanum rostratum</u> | 2. <u>Sphaeralcea coccinea</u> |
|-----------------------------|--------------------------------|

## Vesicular hairs: Subsection C

- |                                 |                           |
|---------------------------------|---------------------------|
| 1. <u>Chenopodium incanum</u>   | 2. <u>C. leptophyllum</u> |
| 3. <u>Monolepis nuttalliana</u> |                           |

## Multicellular glandular hairs: Subsection C

- |                              |                             |
|------------------------------|-----------------------------|
| 1. <u>Linum rigidum</u>      | 2. <u>Plantago aristata</u> |
| 3. <u>P. patagonica</u>      | 4. <u>P. spinulosa</u>      |
| 5. <u>Psoralea cuspidata</u> | 6. <u>P. tenuiflora</u>     |
| 7. <u>Salvia reflexa</u>     | 8. <u>Solanum rostratum</u> |
| 9. <u>S. triflorum</u>       |                             |

## Uniseriate hairs with rounded or blunt tip: Subsection C

- |                                |                              |
|--------------------------------|------------------------------|
| 1. <u>Amaranthus albus</u>     | 2. <u>A. graecizans</u>      |
| 3. <u>Asclepias pumila</u>     | 4. <u>Dyssodia papposa</u>   |
| 5. <u>Kuhnia eupatorioides</u> | 6. <u>Mirabilis linearis</u> |

- |                               |                          |
|-------------------------------|--------------------------|
| 7. <u>Opuntia polvacantha</u> | 8. <u>Salvia reflexa</u> |
| 9. <u>Solanum triflorum</u>   |                          |

Uniseriate hairs with pointed tip: Subsection C

- |                                 |                              |
|---------------------------------|------------------------------|
| 1. <u>Aster ericoides</u>       | 2. <u>Chrysopsis villosa</u> |
| 3. <u>Conyza canadensis</u>     | 4. <u>C. ramosissima</u>     |
| 5. <u>Hedeoma hispida</u>       | 6. <u>H. pulegioides</u>     |
| 7. <u>Helianthus</u> spp.       | 8. <u>Plantago aristata</u>  |
| 9. <u>P. patagonica</u>         | 10. <u>P. spinulosa</u>      |
| 11. <u>Ratibida columnifera</u> |                              |

#### Hair Bases

Circular base

- |                                |                                  |
|--------------------------------|----------------------------------|
| 1. <u>Chenopodium incanum</u>  | 2. <u>C. leptophyllum</u>        |
| 3. <u>Draba reptans</u>        | 4. <u>Gaura coccinea</u>         |
| 5. <u>Lappula</u> spp.         | 6. <u>Monoilepis nuttalliana</u> |
| 7. <u>Oenothera albicaulis</u> | 8. <u>Salvia reflexa</u>         |

Raised, circular base

- |                               |                               |
|-------------------------------|-------------------------------|
| 1. <u>Astragalus agrestis</u> | 2. <u>Helianthus</u> spp.     |
| 3. <u>Oxytropis</u> spp.      | 4. <u>Plantago patagonica</u> |
| 5. <u>P. aristata</u>         | 6. <u>P. spinulosa</u>        |
| 7. <u>Psoralea argophylla</u> | 8. <u>P. cuspidata</u>        |
| 9. <u>P. tenuiflora</u>       |                               |

Whorled base

- |                           |                              |
|---------------------------|------------------------------|
| 1. <u>Aster ericoides</u> | 2. <u>Chrysopsis villosa</u> |
|---------------------------|------------------------------|

- |                                |                              |
|--------------------------------|------------------------------|
| 3. <u>Conyza canadensis</u>    | 4. <u>C. ramosissima</u>     |
| 5. <u>Cryptantha minima</u>    | 6. <u>Draba reptans</u>      |
| 7. <u>Helianthus</u> spp.      | 8. <u>Lappula</u> spp.       |
| 9. <u>Ratibida columnifera</u> | 10. <u>Verbena bracteata</u> |

## Rosette base

- |                             |                                |
|-----------------------------|--------------------------------|
| 1. <u>Solanum rostratum</u> | 2. <u>Sphaeralcea coccinea</u> |
|-----------------------------|--------------------------------|

Stomata Subsidiary Cells

## Anomocytic

- |                                 |                                 |
|---------------------------------|---------------------------------|
| 1. <u>Amaranthus albus</u>      | 2. <u>A. graecizans</u>         |
| 3. <u>Astragalus agrestis</u>   | 4. <u>Chenopodium incanum</u>   |
| 5. <u>C. leptophyllum</u>       | 6. <u>Cryptantha minima</u>     |
| 7. <u>Draba reptans</u>         | 8. <u>Euphorbia fendleri</u>    |
| 9. <u>E. glyptosperma</u>       | 10. <u>E. marginata</u>         |
| 11. <u>Gaura coccinea</u>       | 12. <u>Hedeoma hispida</u>      |
| 13. <u>H. pulegioides</u>       | 14. <u>Helianthus</u> spp.      |
| 15. <u>Kuhnia eupatorioides</u> | 16. <u>Lappula</u> spp.         |
| 17. <u>Liatris punctata</u>     | 18. <u>Oenothera albicaulis</u> |
| 19. <u>Polygala alba</u>        | 20. <u>P. verticillata</u>      |
| 21. <u>Ratibida columnifera</u> | 22. <u>Psoralea argophylla</u>  |
| 23. <u>Solanum rostratum</u>    | 24. <u>S. triflorum</u>         |
| 25. <u>Taraxacum officinale</u> | 26. <u>Verbena bracteata</u>    |

## Anisocytic

- |                            |                         |
|----------------------------|-------------------------|
| 1. <u>Amaranthus albus</u> | 2. <u>A. graecizans</u> |
|----------------------------|-------------------------|

- |                                 |                                  |
|---------------------------------|----------------------------------|
| 3. <u>Aster ericoides</u>       | 4. <u>Chrysopsis villosa</u>     |
| 5. <u>Conyza canadensis</u>     | 6. <u>C. ramosissima</u>         |
| 7. <u>Cymopterus acaulis</u>    | 8. <u>Draba reptans</u>          |
| 9. <u>Dyssodia papposa</u>      | 10. <u>Liatris punctata</u>      |
| 11. <u>Mirabilis linearis</u>   | 12. <u>Monolepis nuttalliana</u> |
| 13. <u>Oxytropis</u> spp.       | 14. <u>Plantago aristata</u>     |
| 15. <u>P. patagonica</u>        | 16. <u>P. spinulosa</u>          |
| 17. <u>Polygonum aviculare</u>  | 18. <u>Psoralea argophylla</u>   |
| 19. <u>Salvia reflexa</u>       | 20. <u>Solanum triflorum</u>     |
| 21. <u>Sphaeralcea coccinea</u> | 22. <u>Taraxacum officinale</u>  |
| 23. <u>Viola nuttallii</u>      |                                  |

#### Paracytic

- |                               |                               |
|-------------------------------|-------------------------------|
| 1. <u>Asclepias pumila</u>    | 2. <u>Linum rigidum</u>       |
| 3. <u>Opuntia polyacantha</u> | 4. <u>Polygonum aviculare</u> |
| 5. <u>Psoralea cuspidata</u>  | 6. <u>P. tenuiflora</u>       |
| 7. <u>Salsola kali</u>        |                               |

#### Diacytic

- |                                |                             |
|--------------------------------|-----------------------------|
| 1. <u>Lepidium densiflorum</u> | 2. <u>Plantago aristata</u> |
| 3. <u>P. patagonica</u>        | 4. <u>P. spinulosa</u>      |

#### Acinocytic

- |                               |
|-------------------------------|
| 1. <u>Opuntia polyacantha</u> |
|-------------------------------|

### Epidermal Cells

#### Irregular cells

- |                                 |                                  |
|---------------------------------|----------------------------------|
| 1. <u>Amaranthus albus</u>      | 2. <u>A. graecizans</u>          |
| 3. <u>Aster ericoides</u>       | 4. <u>Chenopodium incanum</u>    |
| 5. <u>C. leptophyllum</u>       | 6. <u>Chrysopsis villosa</u>     |
| 7. <u>Conyza canadensis</u>     | 8. <u>C. ramosissima</u>         |
| 9. <u>Cryptantha minima</u>     | 10. <u>Cymopterus acaulis</u>    |
| 11. <u>Draba reptans</u>        | 12. <u>Euphorbia fendleri</u>    |
| 13. <u>E. glyptosperma</u>      | 14. <u>E. marginata</u>          |
| 15. <u>Gaura coccinea</u>       | 16. <u>Hedeoma hispida</u>       |
| 17. <u>H. pulegioides</u>       | 18. <u>Helianthus</u> spp.       |
| 19. <u>Lappula</u> spp.         | 20. <u>Lepidium densiflorum</u>  |
| 21. <u>Liatris punctata</u>     | 22. <u>Plantago aristata</u>     |
| 23. <u>P. patagonica</u>        | 24. <u>P. spinulosa</u>          |
| 25. <u>Polygala alba</u>        | 26. <u>Polygala verticillata</u> |
| 27. <u>Ratibida columnifera</u> | 28. <u>Salvia reflexa</u>        |
| 29. <u>Solanum rostratum</u>    | 30. <u>S. triflorum</u>          |
| 31. <u>Sphaeralcea coccinea</u> | 32. <u>Taraxacum officinale</u>  |
| 33. <u>Verbena bracteata</u>    | 34. <u>Viola nuttallii</u>       |

#### Polygonal cells

- |                                |                               |
|--------------------------------|-------------------------------|
| 1. <u>Asclepias pumila</u>     | 2. <u>Euphorbia fendleri</u>  |
| 3. <u>E. glyptosperma</u>      | 4. <u>E. marginata</u>        |
| 5. <u>Kuhnia eupatorioides</u> | 6. <u>Linum rigidum</u>       |
| 7. <u>Mirabilis linearis</u>   | 8. <u>Opuntia polyacantha</u> |

- |                                |                                |
|--------------------------------|--------------------------------|
| 9. <u>Oxytropis</u> spp.       | 10. <u>Polygonum aviculare</u> |
| 11. <u>Psoralea argophylla</u> | 12. <u>Psoralea cuspidata</u>  |
| 13. <u>P. tenuiflora</u>       | 14. <u>Salsola kali</u>        |

## Oval cells

- |                                 |                                 |
|---------------------------------|---------------------------------|
| 1. <u>Astragalus agrestis</u>   | 2. <u>Chenopodium incanum</u>   |
| 3. <u>C. leptophyllum</u>       | 4. <u>Dyssodia papposa</u>      |
| 5. <u>Monolepis nuttalliana</u> | 6. <u>Oenothera albicaulis</u>  |
| 7. <u>Opuntia polyacantha</u>   | 8. <u>Oxytropis</u> spp.        |
| 9. <u>Psoralea argophylla</u>   | 10. <u>Ratibida columnifera</u> |
| 11. <u>Verbena bracteata</u>    |                                 |

Crystals and Glands

## Druse crystals

- |                                 |                                 |
|---------------------------------|---------------------------------|
| 1. <u>Amaranthus albus</u>      | 2. <u>A. graecizans</u>         |
| 3. <u>Asclepias pumila</u>      | 4. <u>Chenopodium incanum</u>   |
| 5. <u>C. leptophyllum</u>       | 6. <u>Monolepis nuttalliana</u> |
| 7. <u>Opuntia polyacantha</u>   | 8. <u>Polygonum aviculare</u>   |
| 9. <u>Salsola kali</u>          | 10. <u>Solanum rostratum</u>    |
| 11. <u>Sphaeralcea coccinea</u> | 12. <u>Viola nuttallii</u>      |

## Raphide crystals

- |                              |                                |
|------------------------------|--------------------------------|
| 1. <u>Mirabilis linearis</u> | 2. <u>Oenothera albicaulis</u> |
|------------------------------|--------------------------------|

## Surface glands

- |                              |                            |
|------------------------------|----------------------------|
| 1. <u>Dyssodia papposa</u>   | 2. <u>Liatris punctata</u> |
| 3. <u>Psoralea cuspidata</u> | 4. <u>P. tenuiflora</u>    |

#### Appendix D. Explanation of terminology used in key.

##### Dicotyledon Structures

Trichomes: Trichomes are outgrowths of the leaves, shoots, roots, and floral parts (Uphof and Hummel 1962). Trichomes are often divided into two parts: the "body" which projects from the surface of the epidermis, and the "foot" which lies within the epidermal surface (Uphof and Hummel 1962). The foot is rarely of the same shape and size as the adjoining epidermal cells; and the latter may differ from the rest of the epidermis, in this case they are called "accessory cells" (Foster 1949). The walls of the trichomes may develop small conical or warty projections and are called papillose trichomes (Amhad 1964).

Trichomes show considerable variation of kind among different species and thus are one of the more important features for taxonomic purposes (Solereider 1908, Foster 1949, Metcalfe and Chalk 1950, Uphof and Hummel 1962, Esau 1965, Fahn 1974). The length, size, and density of these hairs are more likely to vary with environment than are the occurrence of different kinds, so that the former features are of more restricted taxonomic value (Metcalfe and Chalk 1950). Several different kinds of trichomes are used in the key; these different types are defined below.

##### (1) Unicellular

- (a) dentiform- gradually narrowed to a sharp point
- (b) cylindrical- conical or rounded tip, but otherwise more or less the same diameter along entire length
- (c) bristle- ratio of width and height similar, short with rounded or pointed tip

- (d) T-shaped- terminal portion of cell oriented perpendicular to proximal part
  - (e) forked- terminal portion of cell divided into prongs
  - (f) strand- very elongated, narrow hair, often not pointed
  - (g) papillae- similar to earlier stages in development of hairs; slightly elongated and little differentiated, no silicification
  - (h) glandular- secretory hair
  - (i) geniculate- abruptly bent at an angle
- (2) Uniseriate- single row of cells of one or several layers
- (a) filament- a single layered thread-like, flexible hair
  - (b) globose- apical cell bulbous
  - (c) moniliform- more or less constricted at septa and cells more or less swollen (rounded)
  - (d) glandular- secretory hair
  - (e) bicellular
- (3) Multicellular
- (a) stellate- cells of apical portion connected at base with free parts horizontally spreading
  - (b) tufted- cells of apical portion connected at base with free parts ascending or suberect
  - (c) candelabra- superposed whorls of spreading cells
  - (d) vesicles or bladders- greatly distended epidermal cells on stalk or sessile, presumably for reservoirs of water
  - (e) glandular- secretory hair

The basal portion of the trichome may differ conspicuously from the surrounding cells in size, shape, thickness of the cell wall, and contents. In addition the epidermal cells immediately surrounding the



foot may differ from the other epidermal cells. Several types of the trichome foot and accessory cells are used in the key.

- (1) plug- base of hair not as extended laterally or basally in same manner as the surrounding epidermal cells, rather forms a "plug-like" structure
- (2) raised- base or foot of trichome lifted above the general plane of the epidermis
- (3) circular- base of trichome attached to epidermal surface in the form of a circle, not embedded as in the plug
- (4) whorled- accessory cells arranged in a circle around foot, often elongated in relation to other epidermal cells
- (5) rosette- base of trichome several celled along with accessory cells forming structure appearing similar to petals of a rose

Stomata and Subsidiary Cells: The stoma is the pair of guard cells together with the aperture between them (Metcalfe and Chalk 1950). When the cells immediately surrounding the stoma differ from the remaining epidermal cells, they are called subsidiary cells (Metcalfe and Chalk 1950). Stomata are most common on the green aerial parts of plants, particularly the leaves (Esau 1965).

Stomatal frequency not only varies from point to point on a single leaf but depends on the level of insertion of the leaf on the stem; it is strongly influenced by conditions in the habitat (Metcalfe and Chalk 1950). Nevertheless the nature and orientation of the subsidiary cells in relation to the guard cells are important. Metcalfe and Chalk (1950) define five types of stomata according to the arrangement of subsidiary cells.

- (1) anomocytic (irregular-celled) or "ranunculaceous" type: stoma surrounded by a limited number of cells that are indistinguishable in size, shape, or form from those of the remainder of the epidermis.
- (2) anisocytic (unequal-celled) or "cruciferous" type: stoma surrounded by three cells of which one is distinctly smaller than the other two.
- (3) paracytic (parallel-celled) or "rubiaceous" type: stoma accompanied on either side by one or more subsidiary cells parallel to the long axis of the pore and guard cells.
- (4) diacytic (cross-celled) or "caryophyllaceous" type: stoma enclosed by a pair of subsidiary cells whose common wall is at right angles to the guard cells.
- (5) acinocytic type: stoma surrounded by a circle of radiating subsidiary cells

Crystals: Crystals are the end products of the metabolism of the cell.

Crystals differ in chemical composition and form (Fahn 1974). The most common crystals are of calcium salts, especially calcium oxalate (Al-Rais et al. 1971). Many different kinds are referred to in the key: (1) solitary crystals which are rhomboidal, octahedral, elongated, prismatic, or minute; and (2) clustered crystals which are either druses, clusters of solitary crystals forming a mass circular to octahedral in shape, or raphides, thin elongated crystals occurring in bundles.

Epidermal Cell Walls, Cell Orientation, and Cuticle: Epidermal cells differ considerably in size, shape, and outline in different species; but external factors such as light intensity and humidity often have a marked effect on them (Esau 1965). The shape of epidermal cells provides confirmatory evidence, if the identity of the leaf is

suspected on other characteristics. The shape of epidermal cells used in the key are polygonal, irregular, hexagonal, oval, or elongated. The form of epidermal cells is often related to the plant organ. The elongated epidermal cells are often found on structures that are elongated (stems, petioles, or vein ribs of leaves) (Esau 1965). Variations in the anticlinal walls are straight to semi-wavy to wavy. These undulations may be present in the entire depth of the walls or only in their outermost parts (Esau 1965).

The surface of the epidermis may be of several types depending on the projections and cuticle.

- (1) glabrous- devoid of vestiture
- (2) smooth- surface devoid of any undulations
- (3) undulating- irregular surface in cross section
- (4) bullate- surface appearing as if puckered or blistered (Lawrence 1955)
- (5) papillate- bearing minute nipple-like projections (Lawrence 1955)
- (6) muricate- roughened by firm epidermal proliferations scarcely classifiable as hairs
- (7) striated- grooved surface, often radiating in broken or continuous bands from the sides of the stomata and the bases of trichomes (Amhad 1964)

#### Monocotyledon Structures

Epidermis- Short and Long Cells. The epidermis of both Gramineae and Cyperaceae is divided into longitudinal zones. Stomata are located in the intercostal region (between the veins). The costal region is the area above the veins (Metcalfe 1960).

In most Gramineae the epidermis is composed of two distinct sizes of cells (Metcalfe 1960). The epidermis of the Cyperaceae is rarely differentiated into long and short cells (Metcalfe 1971). The larger of these two cell types is called "long cells"; they are elongated horizontally (parallel with the long axis of the leaf) and are relatively narrow vertically (Metcalfe 1960). The other type is called "short cells"; they are more square than the long cells.

Short cells occur in horizontal rows, in pairs, or solitary. They are usually arranged differently in each of the two zones of the lamina. This type of epidermal cell has been referred to as a "silica cell" when it contains a single silica body or a "cork cell" when its walls give the reactions of cork (Metcalfe 1960). In the key the shapes of the silica bodies within the short cells are used extensively.

Stomata. The guard cells in the Gramineae and Cyperaceae are elongated and bone-shaped. The shapes of subsidiary cells in relation to the guard cells are of taxonomic importance. The subsidiary cells are paracytic type. Metcalfe (1960) recognized several types of subsidiary cells differentiated by their shape: 1) triangular, 2) parallel-sided, 3) low-dome-shaped, 4) tall-dome-shaped, 5) variable type.

Silica Bodies. In the Cyperaceae and Gramineae silica is deposited in epidermal cells as silica bodies of various forms; the forms are very different between the two families (Metcalfe 1971). These silica bodies have been classified according to their shapes; they are of considerable value for diagnostic purposes (Metcalfe 1960). In the Gramineae the silica is deposited primarily in short cells. Metcalfe

(1960) recognized several types of silica bodies. Their names are self explanatory: tall and narrow, cubical, round, elliptical, crescent-shaped, cross-shaped, dumb-bell-shaped, angled, elongated horizontally (smooth or sinuous), and oblong. Silica bodies in the Cyperaceae are of completely different types (Metcalfe 1971). The different types were not used in the key since only one sedge was included.

Macrohairs and Microhairs. Hairs are, on the whole, much less common in the monocotyledons than in the dicotyledons (Metcalfe 1960). In addition the hair types (except prickles) of the Cyperaceae are of restricted occurrence, so that the discussion about macrohairs and microhairs refers to the Gramineae. Macrohairs are usually unicellular and form an obvious indumentum on the leaves in many species (Metcalfe 1960). Microhairs are much smaller and are usually bicellular (Metcalfe 1960). Macrohairs vary in length, in flexibility, in thickness of cell walls, and in the extent that their bases are superficial or penetrate between adjacent epidermal cells (Metcalfe 1960). Macrohair types are not extensively used in the key. The one type that is described is the cushion hair; this is a macrohair that has the surrounding epidermal cells larger and more inflated than the base of the hair and often raised above the surface.

Microhairs commonly occur either in the stomatal band or in parts of the intercostal zones that lie between stomatal bands and veins. The presence of microhairs is a very important aid in identification; their shapes are characteristic of certain tribes as

well as species (Prat 1936, Tateoka et al. 1969). However they often are widely spaced and thus absent from small fragments of epidermal tissue. Also microhairs are fragile and become distorted or destroyed quite easily in some species (Metcalf 1960).

Prickle Hairs. Macrohairs are probably homologous with prickles, and it is often difficult to determine in which category the structure should be placed (Metcalf 1960). Prickles are common in both the Cyperaceae and Gramineae (Metcalf 1971). Prickle hairs are robust, sharply but shortly pointed structures with swollen bases. Their short points are usually directed towards the apex of the leaf (Metcalf 1960). Some English writers refer to prickle hairs as "asperities" (Davies 1959). This type of hair is divided into two main groups based primarily on size; prickles are the larger hairs; hooks are the smaller ones (Metcalf 1960). Prickles and hooks may occur alone or together on the same leaf, or they may both be absent. They can be found above or between the veins, but it is more common to find prickles above the veins and hooks between them. Very angular, strongly pointed prickles are common at the leaf margins. Prickle hairs are seldom of value for taxonomic purposes.

Papillae. Papillae are variously shaped protrusions from the outer walls of the epidermal cells (Metcalf 1960). Papillae occur mostly on the long cells, particularly in the intercostal zone; there may be one or more on a single cell (Metcalf 1960). They are common in certain species of grasses and sedges. Their presence is noted in the key but different types are not described.

Major Gramineae Groups. Several authors have used the epidermal characteristics of the grasses to divide them into groups. Prat (1936) used silica cells and epidermal hairs to divide the grasses into two groups: (1) panicoid group which he divided into two major subtypes: the chloricoid characterized by globose or club-shaped bicellular microhairs and saddle-shaped silica bodies, and the eupanicoid subtype with rodlike microhairs and dumb-bell-shaped silica bodies; and (2) festucoid group with round silica bodies and no bicellular or cushion hairs. Metcalfe (1960) used these same two groups, festucoid and panicoid, which he divided into a number of tribes.

Metcalfe (1960) described the panicoid leaf characteristics as: short cells, over the veins, seldom solitary or pairs, but usually in rows; silica bodies, over the veins, saddle-shaped, cross-shaped, dumb-bell-shaped, or nodular; macrohairs present and commonly in intercostal zones; microhairs almost always present; stomata commonly with subsidiary cells triangular or dome-shaped. His description of the festucoid type was: short cells, over the veins, usually solitary and paired, seldom in rows; silica bodies tall and narrow, round, elliptical, crescent-shaped, oblong, and elongated; macrohairs, when present, usually with broad superficial bases; microhairs absent; stomata usually with dome-shaped or parallel-sided subsidiary cells.

Using the system of Metcalfe (1960) the genera of grasses in this study were classified as: Aristida, Bouteloua, Buchloe, Munroa, Schedonnardus, and Sporobolus of the panicoid type; Agropyron, Bromus,

and Festuca of the festucoid type. The third couplet of Section II of the key represents the division of these two groups.